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1914: January, February, March, April, September, October, December.

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1919: Any issue, especially November.

1920: Any issue, especially January.

SUPPLEMENT, No. 3.

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ALFRED J. HENRY, Editor.

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APRIL, 1922.

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DISCONTINUANCE OF CHART I—HYDROGRAPH OF SEVERAL PRINCIPAL RIVERS.

Beginning with this issue, the above-named chart will be permanently discontinued and the serial numbers of the remaining charts regularly published will each be advanced one number; thus the previous No. II will now be No. I, etc.

The information carried by this chart is published in tabular form, annually, in the volume *Daily River Stages*. Considerable inquiry shows that the purpose of the chart thus discontinued will be equally well served by the data of *Daily River Stages*.—EDITOR.

FORMATION AND MOVEMENT OF WEST INDIAN HURRICANES.

By EDWARD H. BOWIE, Meteorologist.

[Weather Bureau, Washington, D. C., May 3, 1922.]

SYNOPSIS.

The physical features of the hurricane are fairly well understood. The explanation of the process of formation of the hurricane remains in more or less dispute, there being two hypotheses that attempt to satisfactorily explain its origin. There are reasons for believing that countercurrents, having their origin in differences in temperature over large geographic areas, initiate the conditions that give rise to the system of gyrating winds; that the condensation of water vapor supplies the energy necessary to maintain them through considerable periods of time. The movement of the hurricane is generally attributed to the general drift of the air in the region of the hurricane. The daily synoptic weather charts and the observations of the free-air directions and speeds of the winds in regions contiguous to hurricanes appear to indicate that hurricanes are carried forward on the border of the major wind system (the northeast trade) of the tropics, and that as this wind system changes its direction the course followed by the hurricane is changed to correspond thereto.

The hurricane.—To the cyclone of the West Indies has been given the name *hurricane*, a vast system of gyrating aerial currents, surrounding a central small or relatively small and more or less circular region of calms known as the eye of the cyclone. The movement of the winds around this center is counterclockwise, with varying degrees of inclination and at speeds proportional to the steepness of the baric gradient. The physical features of the hurricane are fairly well understood. According to Bigelow and other writers, the approach of a hurricane is usually indicated, when the observer is in a position to make such observations, by a long swell on the ocean, propagated to great distances and forewarning the observer by two or three days in rare instances. A rise in the barometer at times occurs before the gradual fall sets in, which fall becomes very pronounced on the near approach of the center; fine wisps of cirrus clouds are first seen, which surround the center to a distance of 200 miles or more; the air is calm and sultry and the usual afternoon thundershowers are suppressed; this is gradually supplanted by a gentle breeze, and later the wind increases to a gale, the clouds become matted, the sea rough, rain falls, and the winds become gusty and dangerous as the vortex core comes on. Here is the indescribable tempest, dealing destruction, impressing the imagination with its wild exhibition of the forces of

nature; the torrents of rain, the cooler air by reason of the falling rain, all the elements in an uproar, indicate the close approach of the center. In the midst of this turmoil there is a sudden pause, the winds almost cease, the sky clears, the waves, however, rage in great turbulence. This is the eye of the storm, the core of the vortex, and it is, perhaps, 20 miles or less in diameter, or one-thirtieth the diameter of the whole cyclone. The respite is brief and is soon followed by the abrupt renewal of the violent wind and rain, but now coming from the opposite direction, and the cyclone passes off with the several features following each other in the reverse order.

Region of first appearance.—The hurricane belt of the North Atlantic Ocean extends entirely across the ocean in low latitudes, but in so far as we are concerned it may be described and defined as that area extending from longitude 56° west to 95° west and from latitude 10° to approximately latitude 25°, or roughly the Caribbean Sea, the Gulf of Mexico, and the waters adjacent to the West Indian Islands. There are, of course, instances where hurricanes have entered this area from the eastward, but during a period of 35 years 90 per cent of the hurricanes of these waters according to Fassig, have had their origin within and not without this area. There is a well-marked belt of maximum frequency through the northern half of the Caribbean Sea, extending almost due west from the Windward Islands to Yucatan. During the greater part of the year this region and the water areas to the north and east are under the influence of the more or less permanent area of high barometer of higher latitudes, and the northeast trade flows entirely over it, but occasionally the northeast trade withdraws from this region and there is left a region of very slight baric gradient, more or less homogeneous temperature distribution in the horizontal, and feeble winds. It is during such times that hurricanes are likely to be found in these waters. Some years pass without hurricane formations; other years are notable for their frequency.

The formation of hurricanes.—We do not know all the facts which would permit an authoritative and unquestioned explanation of the origin of a hurricane. That

remains one of a number of meteorological problems awaiting exact solution. Nevertheless, a number of hypotheses accounting for the origin of hurricanes are to be found in the literature having to do with this problem, but which is the correct one it is now difficult and next to impossible to say. Because opinion is more or less at variance, there follow brief summaries of the expressions by several writers on the subject of hurricanes, or, to use the more general name, tropical cyclones.

Ferrel, writing in the *Nashville Journal of Medicine and Surgery*¹ on "Winds and Currents of the Ocean," expressed the then prevalent idea that hurricanes are generally supposed to be produced by the meeting of adverse currents, which produce gyratory motions of the atmosphere at the place of meeting; that they may receive their origin and first impulse in this way seemed to him very probable, but that violent hurricanes, extending over a circular area of nearly 1,000 miles in diameter and continuing for 10 days, depend upon any primitive impulse alone, seemed to him very improbable. Later in the same paragraph (p. 13) he evidently gives his own conception of the causes which give rise to tropical and extratropical cyclones, for he says—

For if even any part of the atmosphere should receive such an impulse as to produce a most violent hurricane, friction would soon destroy all motion and bring the atmosphere to rest. Besides, no gradually accelerated motion can depend upon a primitive impulse alone, even where there is no friction. Hurricanes, then, and all ordinary storms, must begin and gradually increase in violence by some constantly acting force, and when this force subsides friction brings the atmosphere to a state of rest.

Ferrel then definitely espouses Professor Espy's theory of cyclones and rains—viz, that all cyclones are produced by an ascending current of warmer air saturated with moisture and that this current is kept in motion by the continual rarefaction of the atmosphere above by means of the latent heat given out as the vapor is condensed when it ascends to the colder regions above.

In later years, particularly when engaged in the deliberate study of the motions of the atmosphere in the early eighties, while in the Signal Corps he postulated the conditions under which a cyclone might be generated. This will be found in a work which, unfortunately, has not received as wide distribution as could be wished; the work referred to is officially known as Appendix No. 71 to *Annual Report of the Chief Signal Officer, 1885*, but is better known as "Recent advances in meteorology."

During this period Ferrel found opportunity to make a careful review of the investigations of others and his own work had reached an advanced stage toward maturity. It is interesting, therefore, to note that he still attributes the origin of cyclones to thermal causes such as would give rise to interchanging motions between the interior and the exterior of a somewhat circular-shaped area of temperature abnormality. The motions thus initiated when coming under the deflective influence of the earth's rotation must take on cyclonic character.

Before passing to his most recent and final conclusions on the subject I wish to introduce two brief statements which show his state of mind with reference to the existence of ascending currents not clearly of convective origin. Speaking of the northeast trades of the Atlantic he says:²

Before arriving at the calm belt they (the northeast trades) are deflected upward, and in the central part of the belt there is necessarily a vertical ascending current, for all the air which comes in from both sides must ascend and return toward the poles as a countercurrent. * * * As there is a constant pouring in of air nearly saturated with vapor from both sides of the calm belt, and an ascent there, there is almost a continuous and very abundant fall of rain every day.

See also in this connection, C. E. P. Brooks and H. W. Braby: The clash of the Trades in the Pacific. *Quart. Jour. Royal Met. Soc., Jan., 1921*; abstract in *Mo. WEATHER REV., March, 1921*.

Ferrel in his recent and last work³ begins the chapter on cyclones with a discussion of the general circulation of the atmosphere which would arise on an earth with a homogenous surface as a result of the temperature gradient between the Equator and the Poles. He then passes to a consideration of the disturbances in the general circulation on account of the nonhomogeneity of the earth's surface and to that class of temperature disturbances which give rise to monsoon winds. After this he takes up another class of temperature disturbances which extend over a comparatively small part of the earth's surface and are mostly neither fixed to any part of the earth's surface, nor do they continue generally for a great length of time and hence they are of a more local and temporary character than the others. In this class of disturbances there is a gyratory motion around some central point; hence the name cyclone.

Following his earlier conclusions he reaffirms his belief in the thermal origin of cyclones. He does not postulate a core of warm air in the cyclone which has passed the initial state and has moved many miles from its place of origin; hence the announcement that the center of the cyclone is cold as compared with the anticyclone does not necessarily affect the validity of Ferrel's conclusions, despite, however, the fact that there are no observations to prove that the center of the cyclone area at the time it is forming is warm. His fundamental assumption is that if the air over any portion of the earth's surface is warmer at all altitudes than that of the surrounding parts at the same levels it is lighter, and therefore forced to rise and flow out in all directions. This decreases the pressure at the earth's surface over this area, but increases it a little over the surrounding parts; and thus there arises a pressure gradient from the exterior to the interior below, which causes a flow of air in from all sides to supply the ascending current. Ferrel is careful to state, however, that this modification of his view seems to have been overlooked, that it is not necessary in order to have such a circulation, that all the strata of air from top to bottom shall be warmer than in the surrounding parts, but only that there shall be such a disturbance of the equality of temperature that the pressure of any part of the interior is less than that of the exterior part.

The above has reference to the initial conditions which are assumed to give rise to the cyclone, not to the conditions which may obtain after the cyclone has started on its path. The temperature of the air column will then be determined in a very large measure by one or more circumstances—first, its geographic position with reference to land and water surfaces; second, its remoteness from oceanic winds; third, the latitude and the general movement of the atmosphere of the region in which it exists; and, finally, by the temperature of the inflowing winds.

Studies of European investigators, Dines in particular, have shown that the central core of the European cyclone is cold as compared with the core of the anticyclone. For the United States, or rather for that part for which observations are available, this view is not supported, for it is found that the eastern, or front, side of the cyclone is warm and the rear cold; accurately speaking the highest temperature is found not at the center, but a little to the east of the center in the regions east of the Rocky Mountains. No observations are available for the free air in cyclones entering the continent from the

¹ Later reprinted as *Professional Paper of the Sig. Ser. No. XII*.

² *Recent Advances*, pp. 226-227.

³ *A Popular Treatise on the Winds*, 1889.

Pacific Ocean, but surface observations would lead us to believe that the eastern side of the winter cyclone of our northwestern States and British Columbia is cold as compared with the western or rear side, or the opposite temperature distribution to that found elsewhere in the United States. In the Tropics, where the latitudinal temperature changes are small, we should expect a rather uniform temperature distribution around a cyclone. If it were true that all cyclonic centers are cold and anticyclonic centers warm to all altitudes, then we should expect to find the seat of maximum intensity in the cyclone at very high altitudes, and we might rightly say that the surface phenomena of the cyclone are to be likened to undertow.

Against the views of Professor Ferrel will be found objections by many cyclonologists. For example, a writer in the *Barometer Manual*⁴ in discussing the convectional theory takes the view that—

The idea was that air heated at the surface became lighter than its environment, rose upward forming a core of warm air, the ascending air was replaced by air flowing in from all sides to fill up the vacant place, the inflowing air was diverted from its immediate object by the rotation of the earth, and so a cyclone was formed; and where on the other hand, cold air descends, an anticyclone. There is, unfortunately, no sufficient foundation of truth in this representation. First, the heated air rises truly enough, but in threads, not in masses, and a rising mass would lose temperature at the rate of 1° F. for 190 feet of ascent, and therefore the height it will rise depends, first, upon how much its temperature has been increased and, secondly, upon the rate at which the temperature of the environment falls off. If that air were of uniform temperature, the rising process would begin with the first increase of temperature, but soon cease, and the simple process of a column of rising air would never even begin. If, on the other hand, the temperature of the environment fell off at the maximum rate of 1° F. for 190, no sooner had the heating begun than the heated air would go off to the top of the atmosphere inevitably. Consequently the behavior of the heated air depends not so much upon its being heated as on the structure of the surrounding air, which is not given in the data. Secondly, the cyclone (or anticyclone) is not specially a surface phenomenon; its features are more pronounced and it reaches its best development away from the surface, where friction interferes, and when free of the surface the flow toward the core of the cyclone which was supposed to initiate the cyclone does not exist. Thirdly, the core of the cyclone is not warm compared with the core of the anticyclone, except occasionally in the surface layer, for the upper part of the anticyclone is the warm region and the upper part of the cyclone the cold. Fourthly, as we have already seen in the experiments with Dines' machine a vortex is not formed in air over a hot surface in the space through which the heated air rises. If the air is rising, the vortex is formed in the space underneath where convection begins. If there is a cyclone in the atmosphere and we want to find convection as a cause for it we ought to look for the source of the convection at the top and not at the bottom.

Davis⁵ after describing in detail the evidence in support of the conclusion that tropical cyclones are essentially convectional phenomena on a large scale, remarks that—

They (tropical cyclones) occur in seasons and regions where high temperatures prevail; that they are most effectively aided by abundant condensation of water vapor from air at high temperatures; their circulation is in every way like that which we should expect would follow from a convectional process on a rotating earth. Yet it must be noted that the essential fact on which the belief in their convectional character should depend is not yet a matter of direct observation, for it has not yet been directly shown that the temperature of the cyclone mass is higher than that of the surrounding atmosphere at corresponding altitudes. If observations on mountain peaks should in the future show that the cyclonic mass is not warmer than the surrounding air, the convectional theory of tropical cyclones would have to be abandoned and some other theory devised to explain the phenomena.

Continuing, Davis says, that—

The student should therefore hold the convectional theory in mind as being well supported by reasonable evidence, and yet still lacking

the final element of direct demonstration; he should remember the evidence that leads to the conclusion here regarded as the most probable one; he should not memorize the conclusion alone.

Now, as a matter of fact, observations in the free air in and around a tropical cyclone are not available, but the temperature observations at the surface of the area occupied by a tropical cyclone do not show readings above those of the surrounding regions. In the center of the cyclone—i. e., the eye of the cyclone—the observations are contradictory—in some cases there is a rise, in some no change, and in other cases a fall in temperature.

From the viewpoint of the advocate of the convective origin of cyclones the causes that give rise to it should be looked for in the environment of the cyclone; that which takes place beyond the outer limits of the cyclone proper may be considered as having nothing to do in the genesis of these perturbations. The other school would have us look far beyond the immediate area of the cyclonic formation for its cause. In other words, look to the primary or general wind systems and their interactions for the cause of the local traveling cyclones and anticyclones and also for the cause of other unusual meteorological conditions as well. Hence we find in the literature on cyclones many references to and the parts played by the major winds currents. In fact it appears that the importance of these major air currents in the development of cyclones was the more or less commonly accepted view previous to the middle of the nineteenth century. Thus, we find, for example:⁶

The statement that in early times Dove spoke of the storms (cyclones) of the north temperate zone as occurring between two great currents of air, the northerly, or polar, and the southerly, or equatorial current, and many writers, rather prematurely, taught that great storms (cyclones) were generated in the region between these currents. To this idea two objections were made—namely, that, on the one hand, the polar and equatorial currents were too far apart and too feeble to have any such interaction on each other and generate such violent winds. On the other hand, if this were the sole cause of the hurricane, the latter would soon die away by reason of the resistances to the motion of the wind, and some regenerating process must be discovered in order to explain the generally steady increase in the intensity of such hurricanes up to the maximum before they begin to die away. After many years of discussion on these points it seems now to be generally admitted that a hurricane may begin in the space between opposing currents from the north and south quite as easily in a region where buoyant air is rising and cloud and rain being formed, because there is a slight diminution of the pressure between such opposing wind currents sliding past each other, a diminution sufficient to induce a slight indraft and the formation of a gentle whirl. As to the maintaining power, however, it still appears likely that the principal source for this must be found in the condensation of moisture, the evolution of latent heat, and the interception of sunshine by the cloud. But we must add to these the further consideration that if the air to the northward is abnormally cold or dry, or that to the southward abnormally warm and moist, then the centrifugal force of the earth's rotation will drive the northerly air toward the equator, while the lighter air, by its buoyancy, is driven northward. Just as centrifugal force acts in separating cream from milk in the separator used in the dairy, while gravity separates the cream from the milk by a slower process in the old-fashioned dairies, so in the earth's atmosphere the heavy air is drawn to the ground by gravity or driven to the equator by centrifugal force, while the lighter air is pushed upward or pushed northward, respectively. The general interchange of air between the polar and equatorial regions is due to differences of temperature, moisture, centrifugal force, and gravity, and is known as the general circulation of the atmosphere. We may therefore say that a whirl, when once started, develops into a hurricane under the combined favorable action of these forces—namely, the general circulation of the atmosphere, the absorption of solar heat by its own clouds, and the formation of cloud and rain with evolution of latent heat by its own internal currents and by the moisture of the air driven into it from without. The relative importance of these three depends upon latitude, and must vary from storm to storm, and from day to day.

⁴ A Barometer Manual, M. O. 61, pp. 24-25, London, 1916—8th ed.

⁵ Elementary Meteorology, p. 206.

⁶ Prof. Cleveland Abbe in MO. WEATHER REV., 32: 373.

Bigelow,⁷ although having previously expressed the opinion to the effect that hurricanes were due solely to convective processes, as stated in the *Yearbook of the Department of Agriculture for 1898*, reached the conclusion from a careful study of the surface and upper air currents of the West Indies that a hurricane is built up on exactly the same mechanical principle as a tornado—namely, by the conflict of two currents flowing together from different directions and having different temperatures, only the hurricane is much deeper than the tornado, the hurricane forming a tube from 4 to 6 miles in height, while the tornado tube seldom exceeds 1 mile in height and that between them, the countercurrents, at the height of about 1 mile, a vortex tube is formed, which, by its gyratory action, extends downward through the lower strata, which latter must be in a more or less quiescent state or else drifting slowly eastward from top to bottom.

In the China Sea and the waters to the east-southeast the atmospheric environment is not dissimilar to that of the West Indies, and hence expressions concerning the formations of typhoons (cyclones) in these regions may be considered as applicable to the West Indies. Doberck⁸ expresses the opinion that typhoons are generated by countercurrents, while Father Algué,⁹ after reviewing the convective and countercurrent theories and quoting Prof. Julius Hann thereon, remarks on the supposition that the origin—that is to say, the primary factor of some cyclones—is precisely the action of opposing currents, originated by the thermal conditions of the atmosphere or by other causes, whose immediate effect is the whirl, from which comes the barometric depression and the consequent alteration of the atmospheric equilibrium which produces the convergent currents. He remarks that in such cases the convergent currents would subsist even though the opposing currents had disappeared, leaving the whirlwind thus formed by virtue of the general causes, just as if it had been formed by the condensation of aqueous vapor over a large area. This process, in his opinion, seems to account for the origin of many of the cyclones of the China Sea.

There has recently been given us a new conception of the part that these more than local wind systems play in the formation of cyclones as set forth by Dr. V. Bjerknes in his theory of the polar front. Of course this theory is made applicable to the extratropical cyclones, but nevertheless it is suggestive in connection with efforts to explain the genesis of the tropical cyclone. In the report of the proceedings of the seventh meeting of the International Commission for the Investigation of the Upper Air¹⁰ he says that the analysis of the daily synoptic charts from the viewpoint of the "life history" of the different air masses has led to the polar-front theory. According to this theory, the successive cyclones of the temperate zones are waves on the boundary surface between the cap of polar air and the surrounding warm air masses, the corresponding boundary line at the ground, "the polar front," accordingly traversing the centers of depressions around the pole. The extreme northern ends of the warm waves coincide with the centers of low pressure and the cold waves of polar air between them constitute the moving wedges of high pressure. He also says that an examination of depressions individually from their formation to their dis-

appearance shows that young depressions correspond to slight waves with small excursions from the equilibrium state, and that later the amplitudes increase simultaneously with a deepening of the depression.

According to Dr. Anders Ångström:¹¹

The latest researches in regard to the constitution of the atmosphere in cyclones and anticyclones have more and more led to an increased realization of the importance of surfaces of discontinuity. The cold and warm currents, which seem to be general constituents and important agents in the cyclones, are separated by relatively sharp boundaries, characterized by sudden changes in temperature, humidity, and wind direction. The examination of the synoptic charts giving the conditions round the north European cyclones have in this point in general supported the ideas put forward by Dove, Bigelow, Margules, Exner, v. Ficker, and Bjerknes. * * * As in many fields of natural research, we are also in dynamic meteorology passing from the belief in the continuity of natural phenomena to an opposite view, where discontinuity prevails.

There have appeared from time to time in the literature on cyclones other than these two principal hypotheses—the convective and the countercurrent—but they have not been given more than passing attention. Now, from what has been stated it would seem that the cause of the origin of the tropical cyclone may be found in the countercurrent theory as to initiation of the cyclonic center, while the convective theory accounts for its maintenance after having started. This conclusion is reached after a consideration of what seems to be the facts in the case. We know that convection is going on more or less generally, but it appears that over the regions where convection is in operation the air does not rise *en masse*, but in filaments, and the visible result is the formation of cumulus clouds and their attendant phenomena, such as local showers, local thunderstorms, and local vortices of a small diameter. It is a common observation, as shown by the daily weather maps, that cyclones do not develop in these areas; moreover, regions of excessively high surface temperature are not places where cyclones are ordinarily formed, rather they form on the borders of such regions. Furthermore, it is difficult to visualize local superheating over the wide expanses of water where tropical cyclones form. Again, if convection were the primary cause of the origin of cyclones we should expect to find them of maximum frequency over the calm belts of the Tropics where there is a superabundance of water vapor and relatively high temperatures over large areas. We should not expect to find, if convection were the cause, the belt of maximum frequency of cyclones the world over in mid-winter and along the border of the region of polar night. (See fig. 1.)

The diagram (on next page) has been prepared from the data of storm frequency shown by Chart 52, *Bulletin A*, Weather Bureau, a summary of international meteorological observations for the years 1878 to 1887, inclusive. Each column represents the number of cyclone centers observed at noon (Greenwich time) in the respective circumpolar belts of 5° in width. For example, between latitudes 45° and 50° there were observed during the period of 10 years cyclone centers to the number of 8,088. It is not to be inferred that no cyclones escaped detection during the 10-year period of observations, but it is to be assumed that the diagram represents the *relative latitudinal frequency* of cyclones for the Northern Hemisphere.

The temperature distribution, at least at the surface, in the tropical cyclone is seemingly one of but minor variations in the several quadrants of the cyclone, while

⁷ Results of nephoscope observations in the West Indies during the years 1899-1903. *MO. WEATHER REV.*, April, 1904, pp. 166-169.

⁸ The Law of Storms in the Eastern Seas. *Hongkong Observatory, No. 2*, Hongkong, 1898.

⁹ *Cyclones of the Far East*.

¹⁰ Publication of the Int. Met. Com., printed at Bergen, July, 1921.

¹¹ Forecasting of Dynamical Changes of Temperature. *Geografiska Annaler*, 1921, H. 3.

in the extratropical cyclone the temperature distribution appears to be different for different regions. In Europe the center, as previously stated, is found to be cold; in the United States east of the 95th meridian the eastern half is warm and the western half cold, while the surface temperature distribution of the cyclones of winter of the North Pacific coast strongly points to a cold front and a warm rear. From this we infer that the temperature distribution, inextratropical cyclones at least, is one purely dependent on whence came the air imported into the cyclonic area.

Now, with regard to the theory that cyclones arise from interactions between the currents arising from the general wind system, there seems to be much in its favor. Bigelow in his studies of the circulation of atmosphere over the West Indian waters, previously referred to, shows that such currents, which he has designated countercurrents, are commonly found. In fact, all regions of maximum frequency of tropical cyclones are bounded by oppositely directed currents of air, and, as stated by

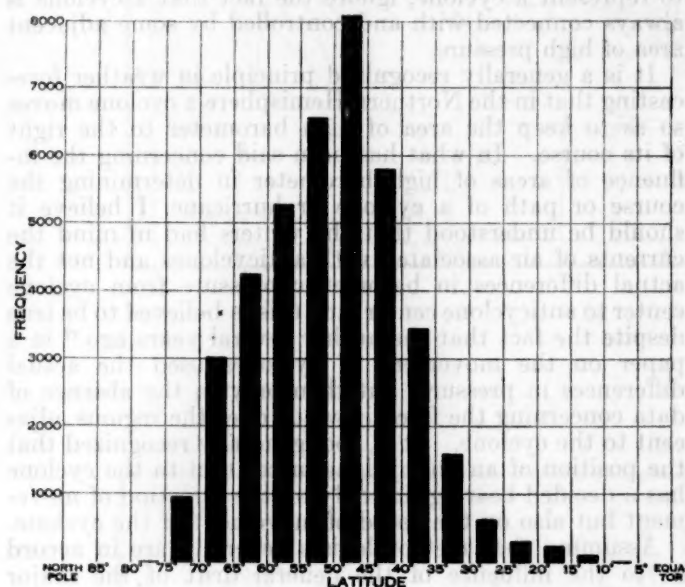


Fig. 1.—Latitudinal variation of cyclone frequency.

Abbe, Bigelow, Algué, Bjerknes, Meldrum, and other writers, it is reasonable to assume that they may have to do with the genesis of a cyclone.

The following by Sir Napier Shaw¹² is suggestive and points directly to the countercurrent theory as containing the explanation of the origin of cyclones and anticyclones:

It is curious, but undeniable, that when a westerly current has an easterly current upon its southern side, the two show no disposition to mix, except possibly to produce fog; they keep an undisturbed anticyclonic region between them as a sort of buffer state. If the westerly current has an easterly current on its northern side, quite the opposite state of things results—the two currents engage one another forthwith, and a circular storm results. Doubtless the consequences are in accordance with the principles of circulation laid down by Prof. V. Bjerknes (MONTHLY WEATHER REVIEW, October, 1900), but to those unfamiliar with the reasonings of hydrodynamics they must seem rather mysterious.

It is altogether probable that these countercurrents obey the law of Buys Ballot to the effect that if one stands with his back to the wind the barometric pressure decreases toward his left and increases toward his right in the Northern Hemisphere, and the reverse in the

Southern Hemisphere. This law is a necessary consequence of the influence of the earth's rotation, and it is generally accepted. Now, we can go further with this law as a basis and say without fear of contradiction that countercurrents will and must maintain a belt of high or relatively high barometer between them when they pass to the left of each other and a belt of low or relatively low barometric pressure between them when they pass to the right¹³ of each other. The difference in barometric pressure from high to low will depend primarily on the width of the countercurrents, the velocity of flow, and the latitude. The only exception to this statement will be found in the equatorial region in the Middle Atlantic and Middle Pacific Oceans, where the northeast and southeast trades merge and flow onward as an easterly wind and without an intervening region of calms. In this case the combined system of winds is subjected to (1) the right-hand deflective influence of the earth's rotation of the Northern Hemisphere for that part of the current actually in the Northern Hemisphere and (2) the reverse for that part of the combined current flowing westward in the Southern Hemisphere. Hence we have the anomalous situation, found nowhere else, of a tendency toward low pressure in the midst of an onward flowing river of air.

Generally these countercurrents and the barometric gradients are in what may be considered to be perfect balance, but it requires no great stretch of the imagination to understand that this is not necessarily always so. If in the case of countercurrents passing to the right the balance is disturbed, we would expect in the case of countercurrents too strong for their gradients a further pulling apart, a diminution or rarefaction of the air aloft over the intervening belt of already low or relatively low pressure and calms, and a welling up of the stratum near the earth's surface. As the welling-up process goes on, the denser air from the contiguous regions flows inward toward the region over which the air has become rarefied, and gyratory motion will necessarily follow from the deflective influence of the earth's rotation. Moreover, the welling-up process will bring about condensation of water vapor and thus an added impetus will be given the incipient cyclonic formation, and as this condensation goes on as fresh vapor-laden air is brought into the cyclonic area energy for its maintenance will always be at hand.

THE MOVEMENT OF HURRICANES.

The student on examining the paths of hurricanes for a considerable number of years, for any given month, plotted on a single chart, must be impressed by the seeming indifference of hurricanes to follow any well-defined path or paths. The plotted paths show no inclination to converge on any given locality. No two hurricanes follow parallel paths throughout their courses from time of origin to time of disintegration. Tracks cross and recross and recurve here and there without seeming to obey any physical law. A considerable number of the plotted tracks show no recurve, and consequently these hurricanes did not pass into high latitudes; and, again, loops are noted in a few of the tracks where seemingly sudden and decided changes in the forces which propelled the hurricanes took place. From what has been stated it will be readily seen that a single track to represent an average path for a given month is of no particular value as an aid to the forecaster in determining the path a

¹² Shaw, Sir N.: *Forecasting the Weather*, p. 286.

¹³ In the Northern Hemisphere the pressure is relatively low between east and west currents when the west current is south of the east.—E. H. B.

hurricane will follow. Moreover, a consideration of the plotted tracks unaccompanied by synoptic charts of pressure, winds and clouds will not be of material aid to the student in his endeavor to unravel and set forth the laws which control the movement of hurricanes. Synoptic charts of pressure, temperature, surface winds, free-air winds, and clouds over wide areas are essential to research problems associated with tropical cyclones. We must look beyond the immediate environs of the cyclone to determine the cause of its being as well as its direction and speed of progression.

Now while there may be considerable diversity of opinion as to exactly how the hurricane has its origin, there seems to be unanimity of opinion as to the cause which controls the hurricane in its movement along its track. The translation of the hurricane is commonly attributed to the general motion of the air over the region, in which the hurricane is found, but even here there is a difference of opinion as to the exact operation of the propelling winds. According to the late Dr. Julius von Hann¹⁴ the influence that a prevailing general current of air exerts upon the progress of a whirlwind that has entered into it evidently consists in this, that the masses of air drawn into the whirlwind have to follow two impulses: One, that which is due to the whirl, and the other, that which is due to their original movements. Therefore, in the region of the trade winds and on the northwest side of a whirl, the motions are most accelerated, but on the opposite side most retarded, and thereby the whirl must receive a tendency to progress toward the northwest. "I believe," says he, "in its principal feature this agrees also with Lommel's theory of the recurving of the paths of cyclones on their leaving the trade-wind system."

The recurve of storms in the West Indies, and over the Gulf of Mexico, according to Weather Bureau *Bulletin A*, is dependent upon general meteorological conditions, and more especially upon the distribution of atmospheric pressure. The anticyclone or high-pressure area of the North Atlantic Ocean lies northeast of the West Indies, and causes east to northeast winds over the southern part of the ocean and the Caribbean Sea. The storms (hurricanes) which develop in the region east of the West Indies, and also those of a more westerly origin, have a tendency to follow the course of the main equatorial current over the Caribbean Sea. This course is doubtless largely influenced by the general drift of the atmosphere in that region, and following the anticyclonic circulation of the winds the hurricanes skirt the western quadrants of the Atlantic high area, and, carried by the general drift of the atmosphere, follow paths which recurve north and northeastward near the southeastern coasts of the United States. As a majority of the hurricanes traced followed the course indicated, it may be considered the usual course of West Indian storms when the average meteorological conditions obtain over the southern and southwestern North Atlantic Ocean and the eastern part of the United States. Some of the more important storms that originate near the West Indies do not recurve, but move westward over the Gulf of Mexico and dissipate over Mexico or the Southwestern States. In such cases high barometric pressure apparently prevents a recurve.

Garriott¹⁵ in his study of tropical storms of the Gulf of Mexico and Atlantic Ocean, in September, says it may be assumed that with a nearly normal distribution and

movement of atmospheric pressure September cyclones will recurve near longitude west 80° and between latitudes north 25 and 28°. He also says that when a cyclone is central east of Cuba and an area of high pressure is advancing eastward over the Gulf and South Atlantic States, the cyclone will probably recurve east of the Bahamas; when the cyclone reaches central Cuba or longitude west 80°, and an area of high pressure is advancing over the west Gulf and Southwestern States, the cyclone will probably recurve over Florida or the east Gulf; when the cyclone reaches the 75th meridian and an area of high pressure is overspreading the interior and eastern districts of the United States with stationary or falling barometer over the west Gulf and the Southwestern States, the cyclone will probably advance westward over the Gulf of Mexico.

Maxwell Hall¹⁶ states that no cyclone is an isolated phenomenon; it is always related to the general distribution of pressure in the latitudes where it is generated, and that the concentric circles, which are usually drawn to represent a cyclone, ignore the fact that a cyclone is always connected with and controlled by some adjacent area of high pressure.

It is a generally recognized principle in weather forecasting that in the Northern Hemisphere a cyclone moves so as to keep the area of high barometer to the right of its course. In what has been said concerning the influence of areas of high barometer in determining the course or path of a cyclone or hurricane, I believe it should be understood that the writers had in mind the currents of air associated with anticyclones and not the actual differences in barometric pressure from cyclone center to anticyclone center, and this is believed to be true despite the fact that the author several years ago¹⁷ in a paper on the movement of cyclones used the actual differences in pressure, but then only in the absence of data concerning the free-air winds over the regions adjacent to the cyclone. It is, too, generally recognized that the position of an anticyclone in relation to the cyclone has a decided bearing not only on the direction of movement but also on the speed of movement of the cyclone.

Assuming that meteorologists generally are in accord as to the influence of the general drift of the major wind currents and the lesser wind currents associated with traveling anticyclones in determining the movements of cyclones or hurricanes, it is essential that the forecaster of such phenomena as attend them should have a clear concept of how this is brought about.

There are printed in connection with this paper Charts 1 to 6, showing the general distribution of pressure attending the movement of the hurricane of August 14 to 17, 1915, across the Gulf of Mexico. It will be noted that the regions of barometric pressure above 30 inches have been shaded to emphasize the relation of the anticyclone to the course of the hurricane. It will also be observed that the path followed by the center of the hurricane was such that high barometric pressure was always to the right of the course the hurricane center followed on any given day. This hurricane was one of unusual intensity during the time it was crossing the Gulf of Mexico, but after crossing the coast line into the interior of Texas its intensity and speed of progression diminished quite rapidly. A further inspection of these charts will show that the center of the hurricane was always on the border of the area of high barometric pressure to the northward, and that as the position of

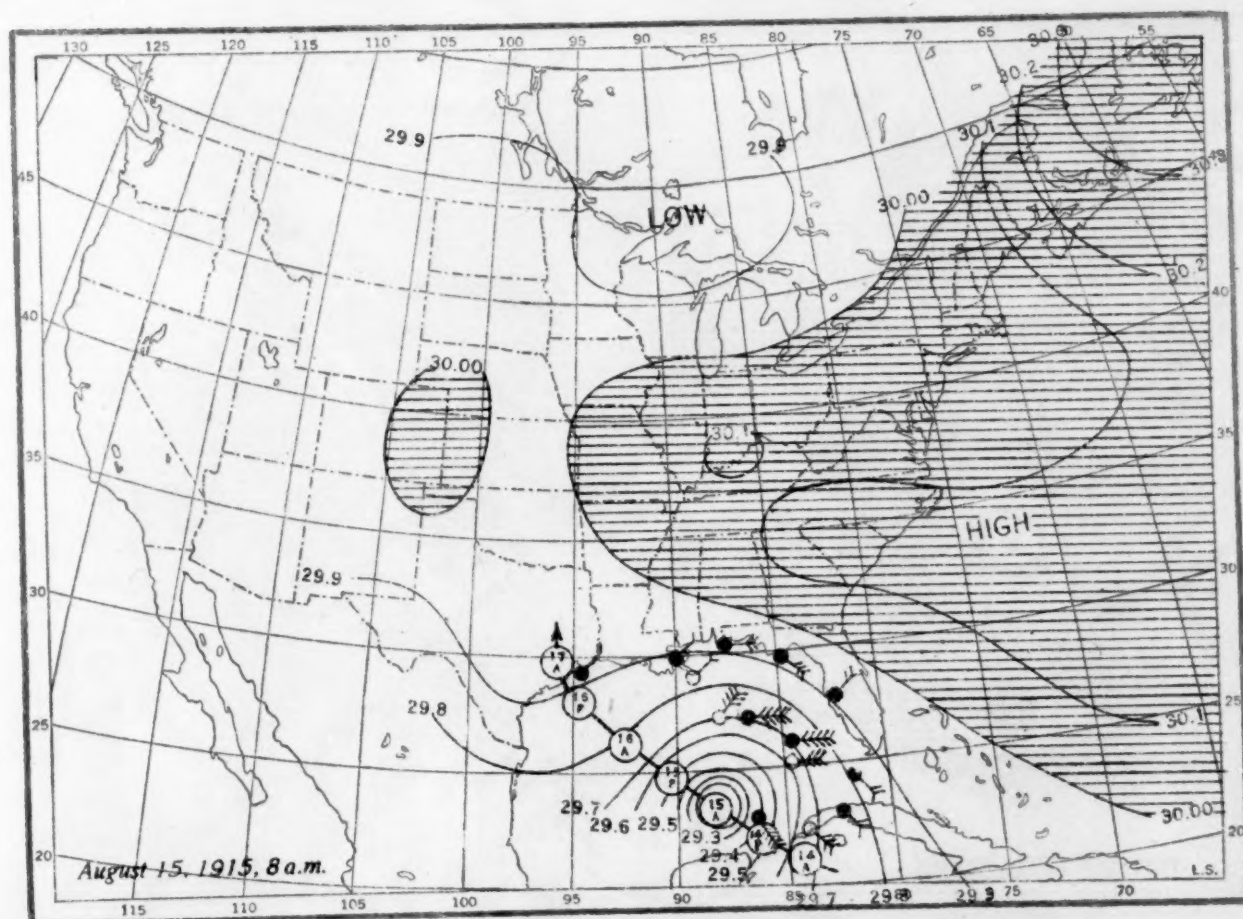
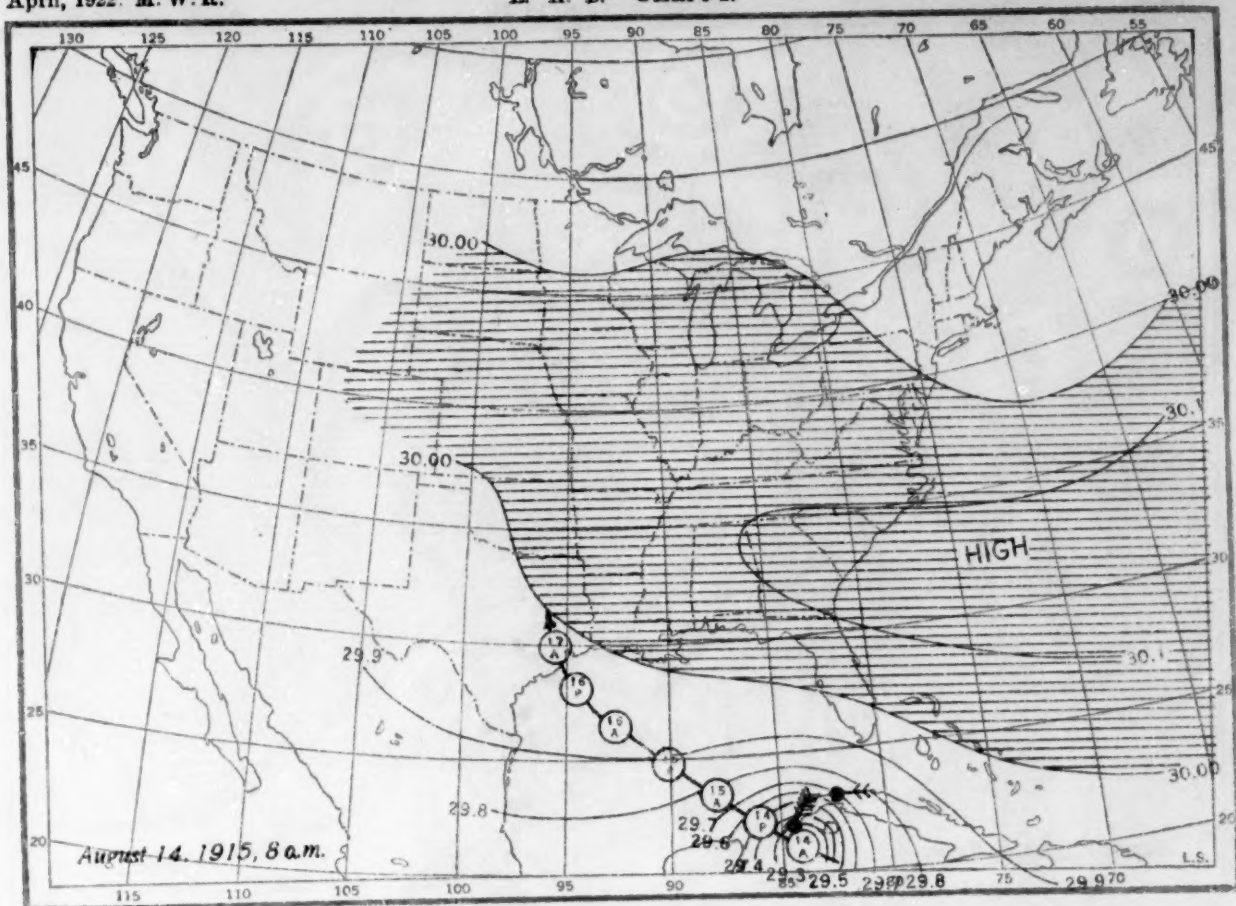
¹⁴ Hann, J., Über die Beziehungen zwischen den Luftdruckdifferenzen und der Windgeschwindigkeit nach den Theoren von Ferrel und Colding-Zeitschrift der *Oester. Gesell. für Meteorologie*, März, 1875, Nr. 6 s. 6.
¹⁵ MONTHLY WEATHER REVIEW, May, 1895, p. 167.

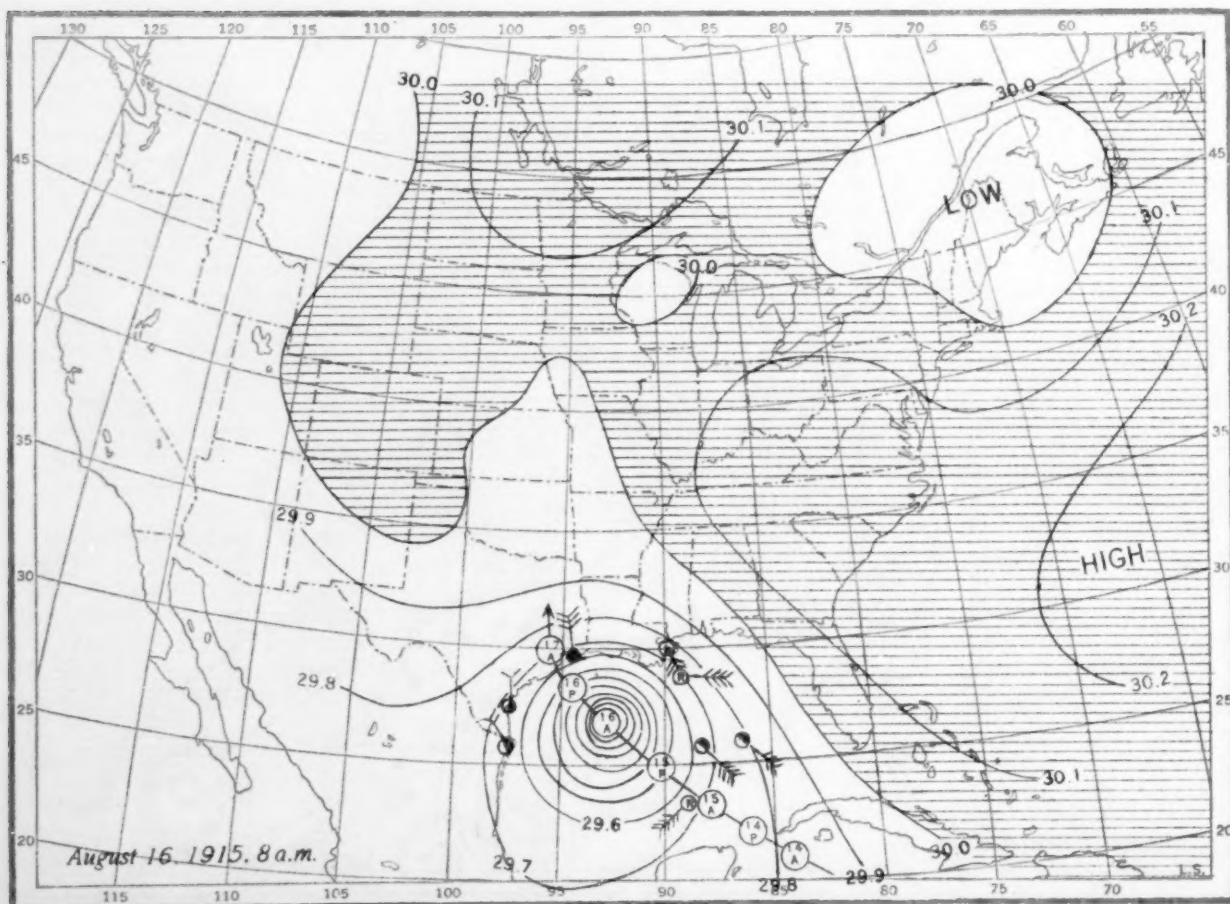
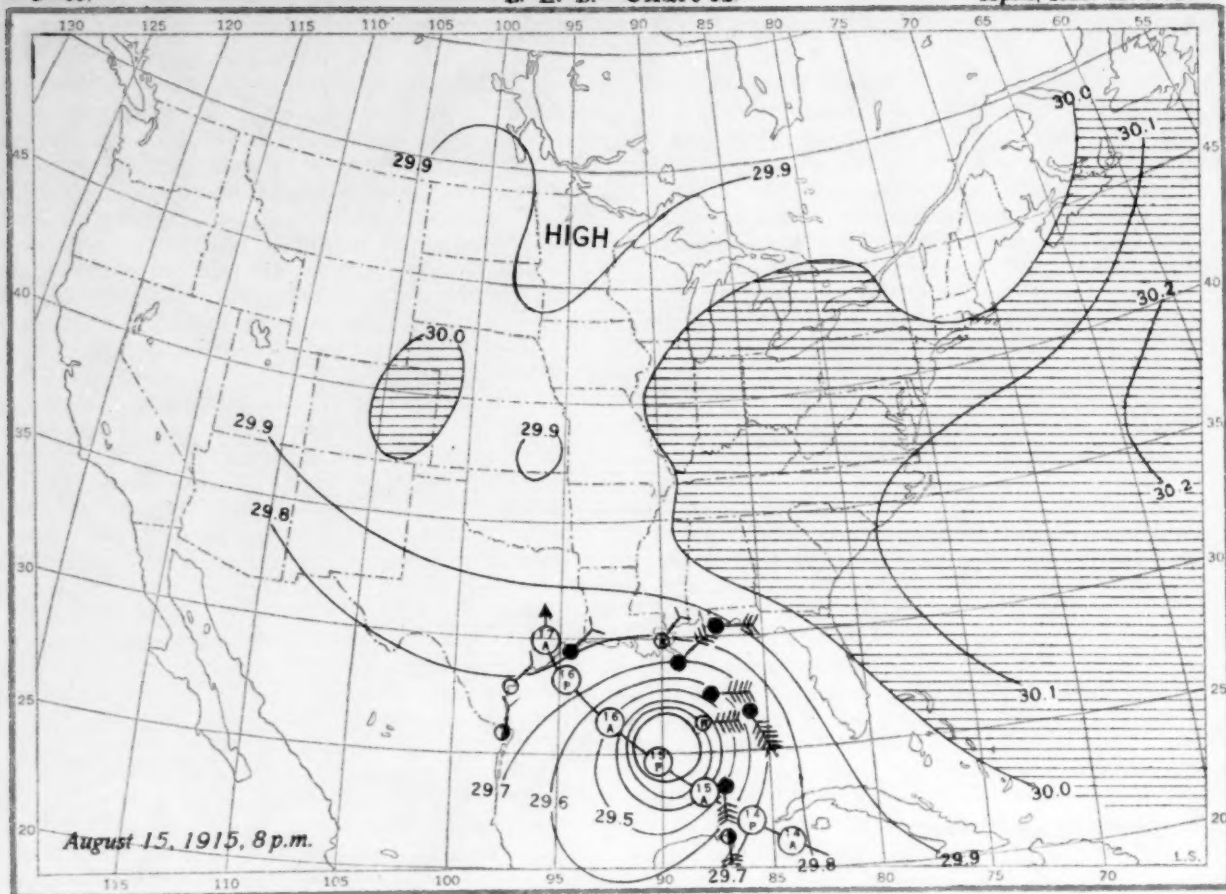
¹⁶ West Indies Hurricanes as Observed in Jamaica, MO. WEATHER REV., 45: 578.
¹⁷ MO. WEATHER REV., 34: 61.

April, 1922. M. W. R.

E. H. B. Chart I.

1-59.

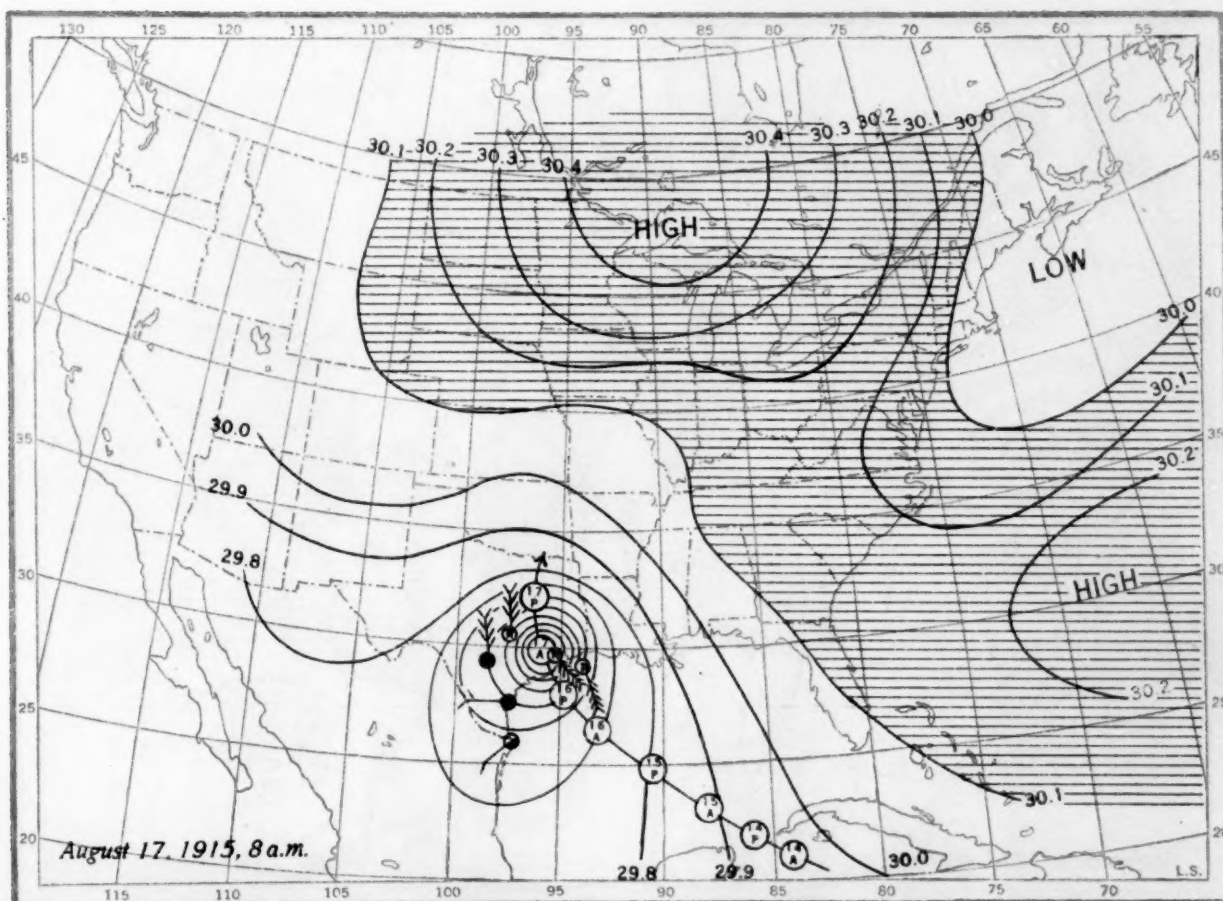
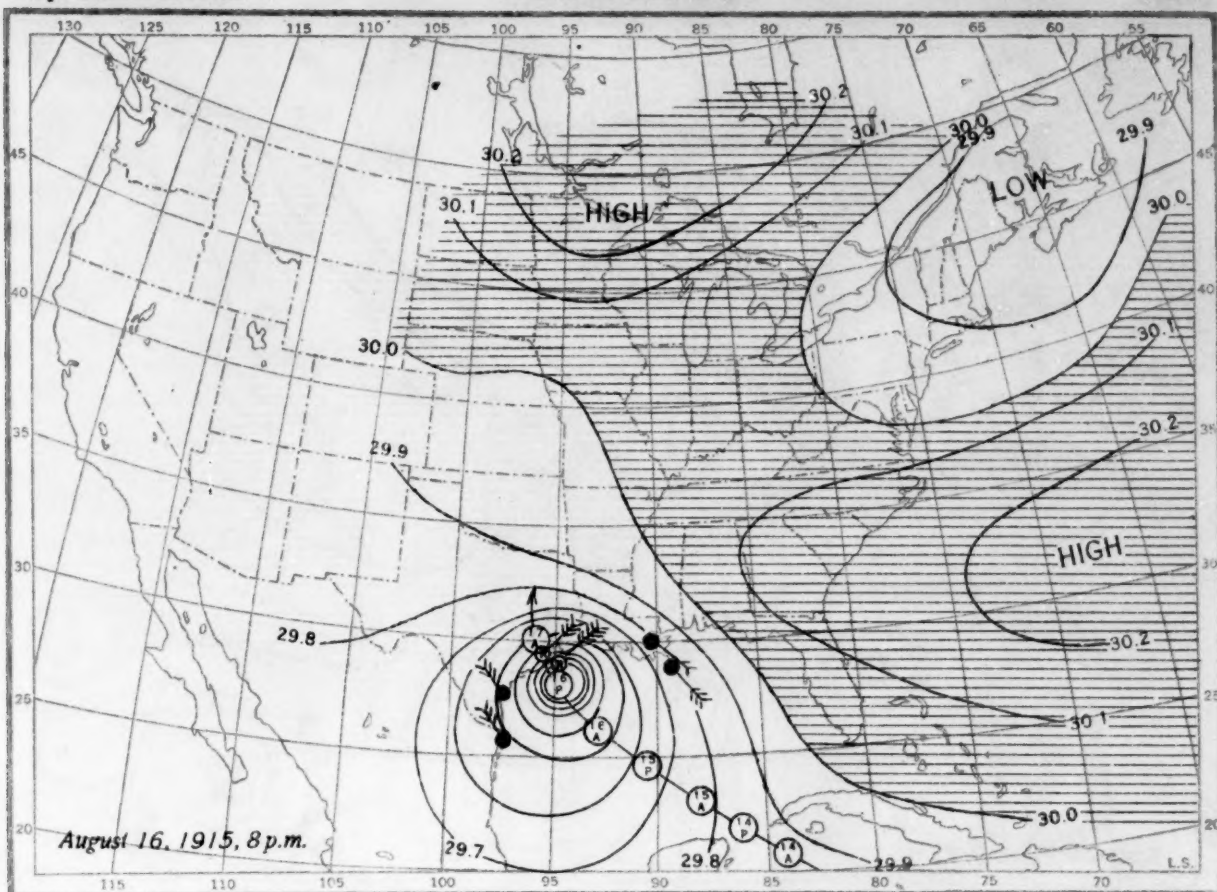


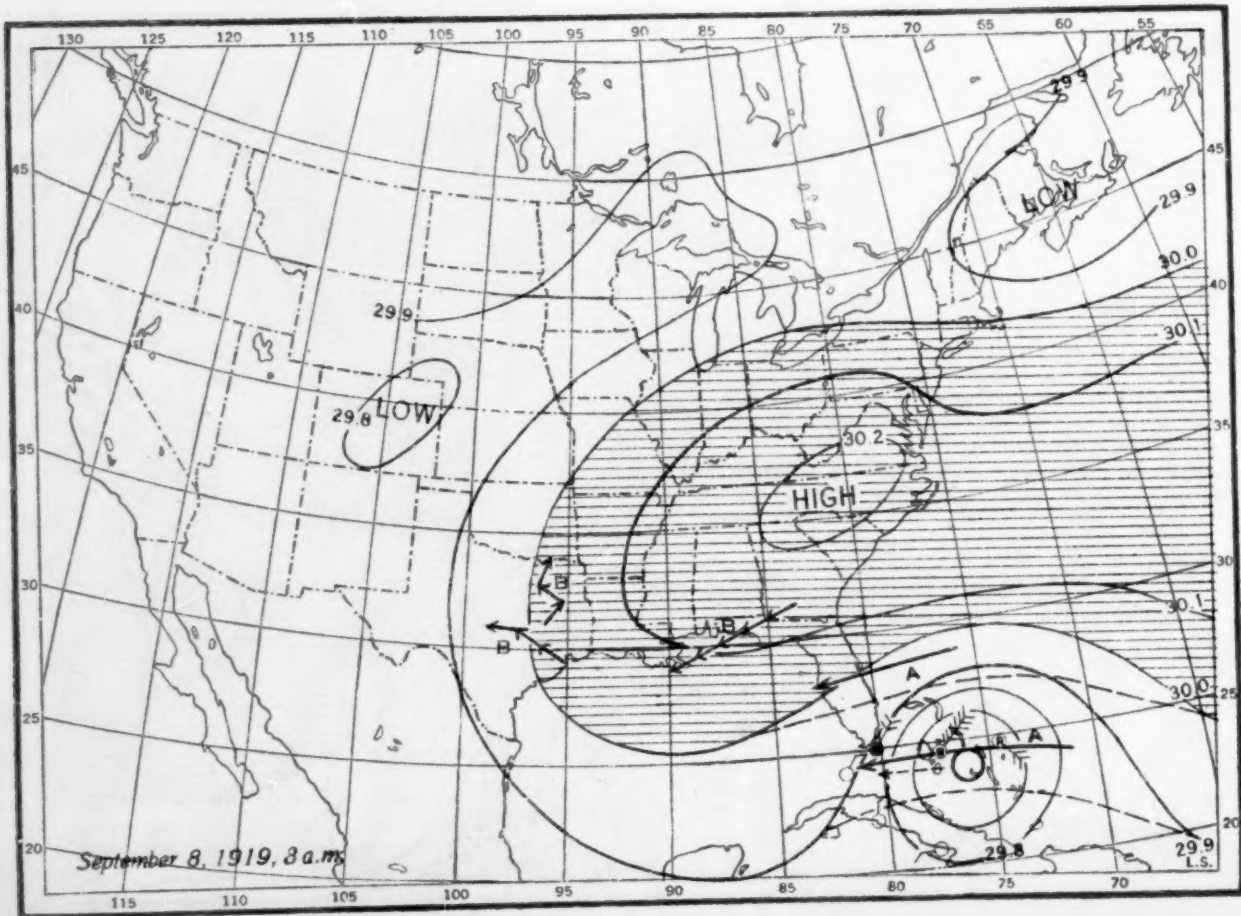
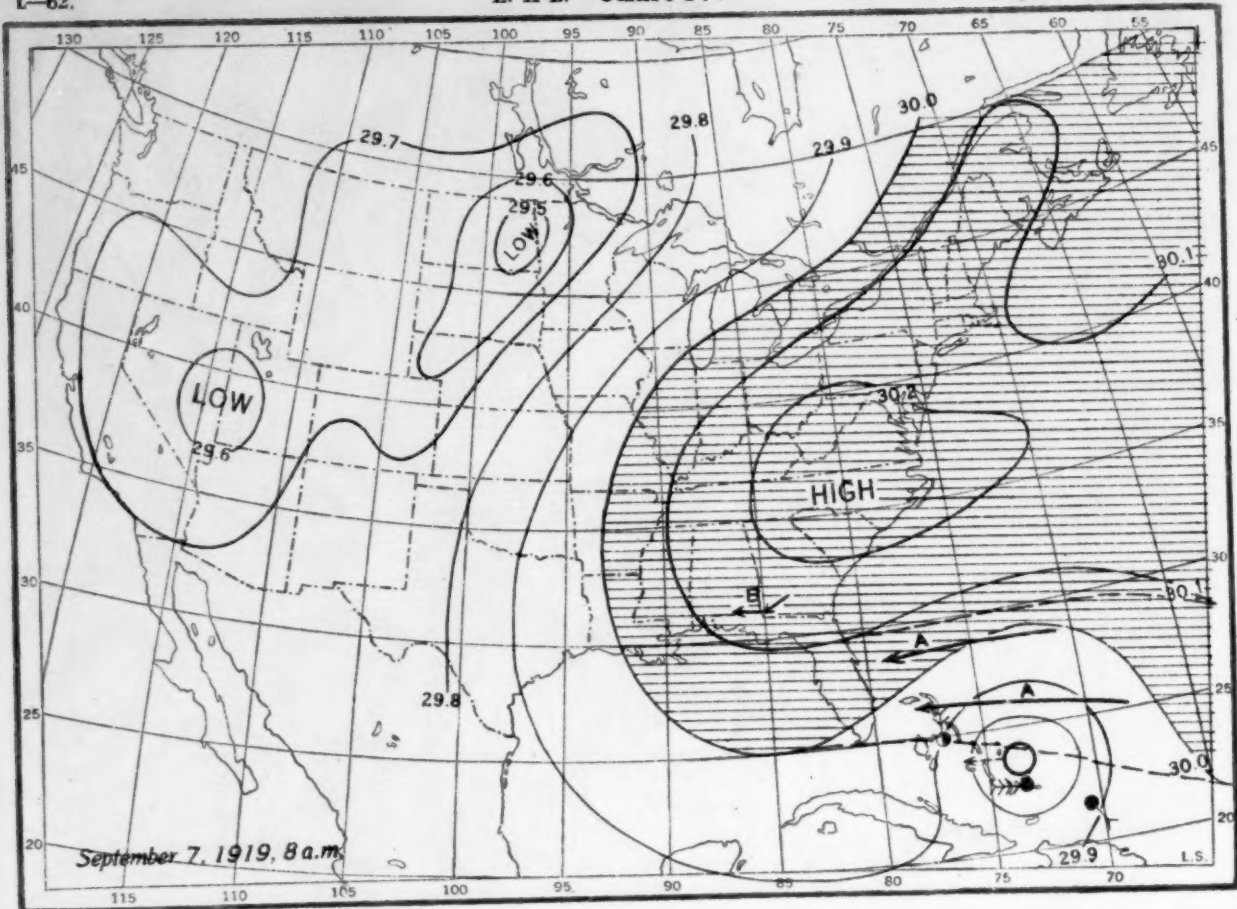


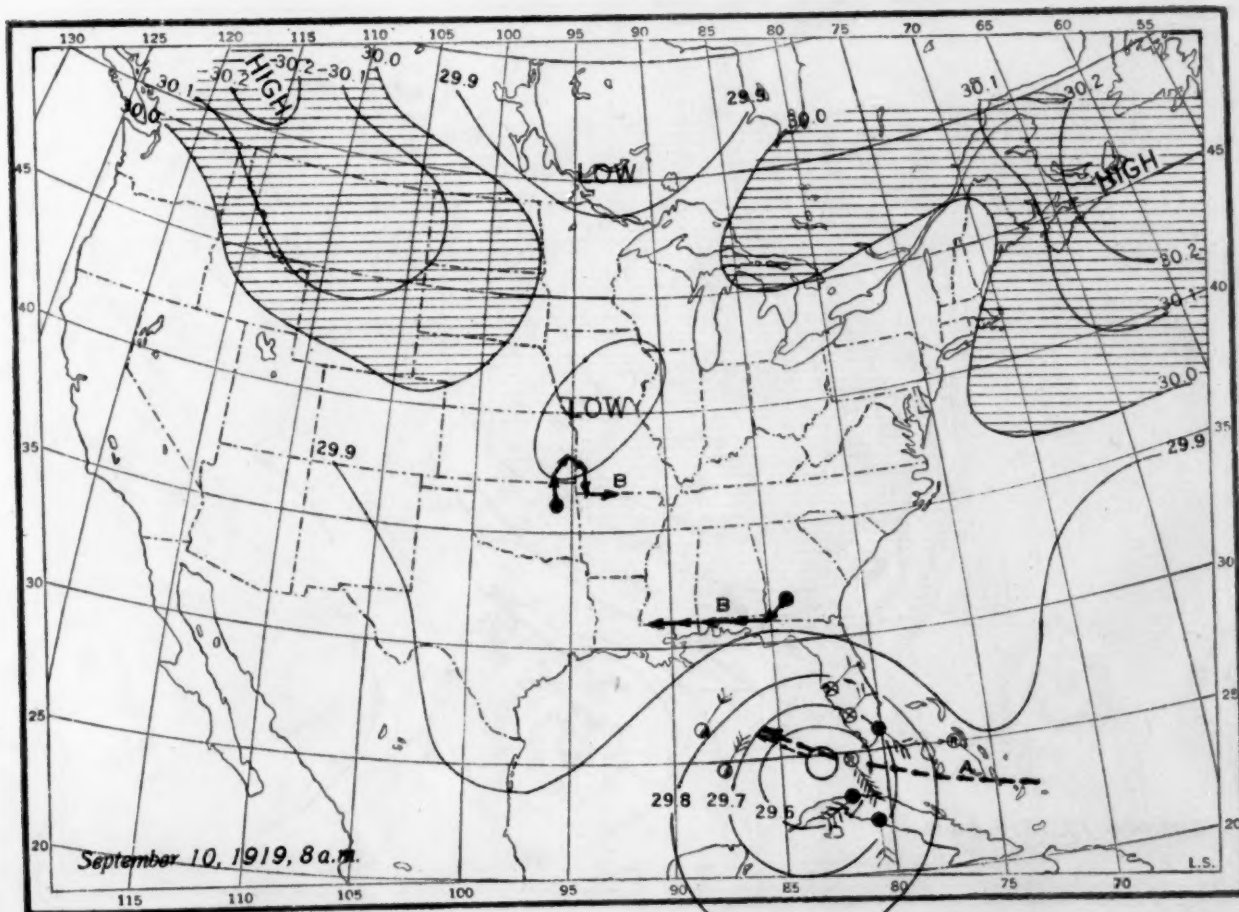
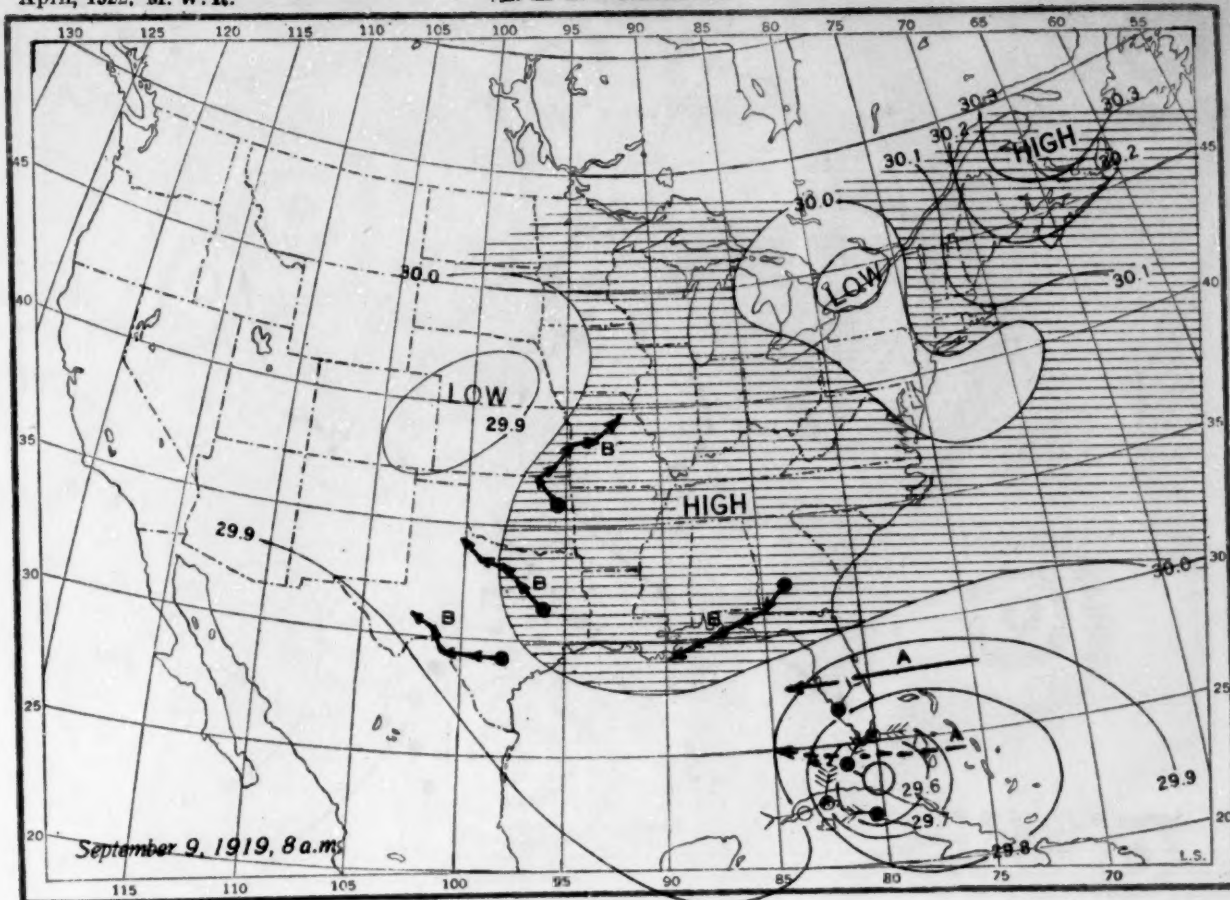
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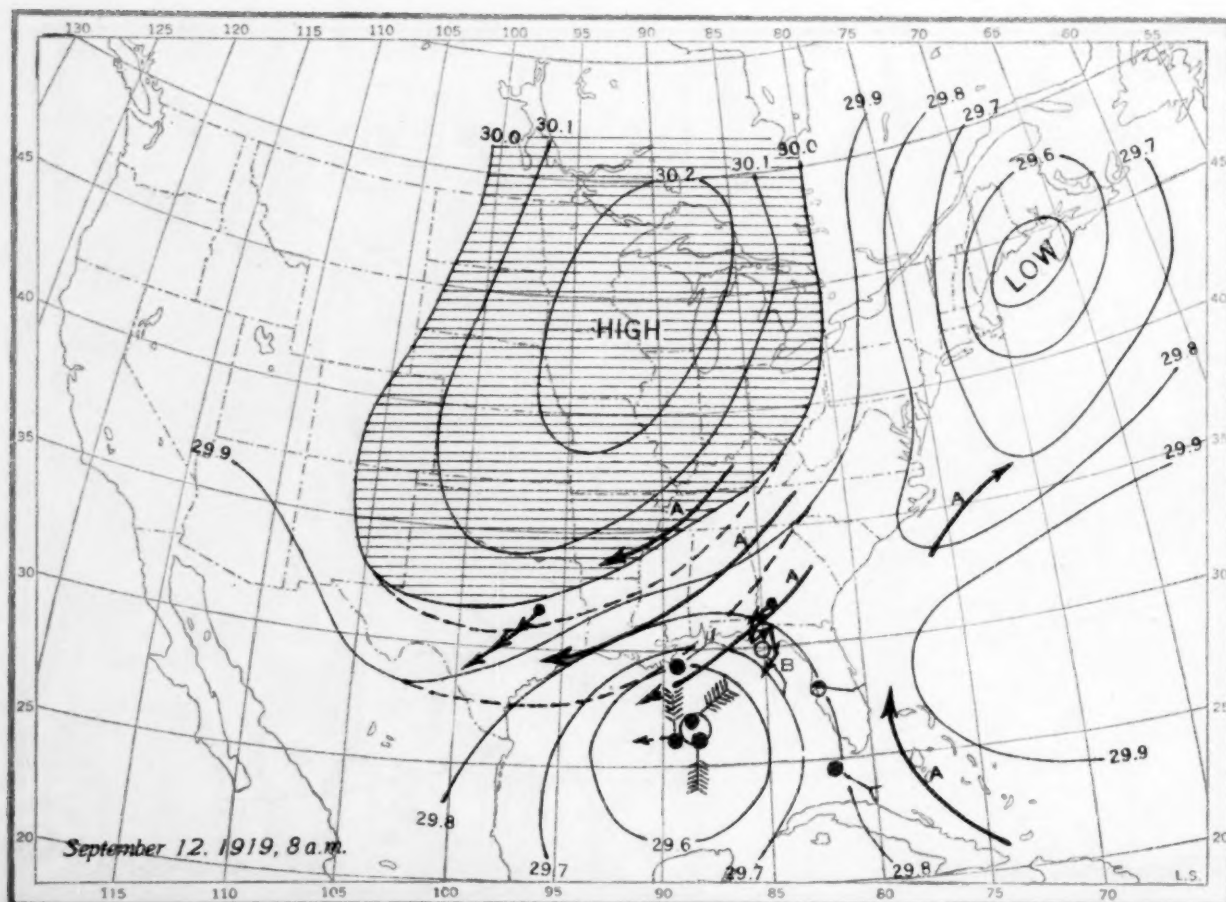
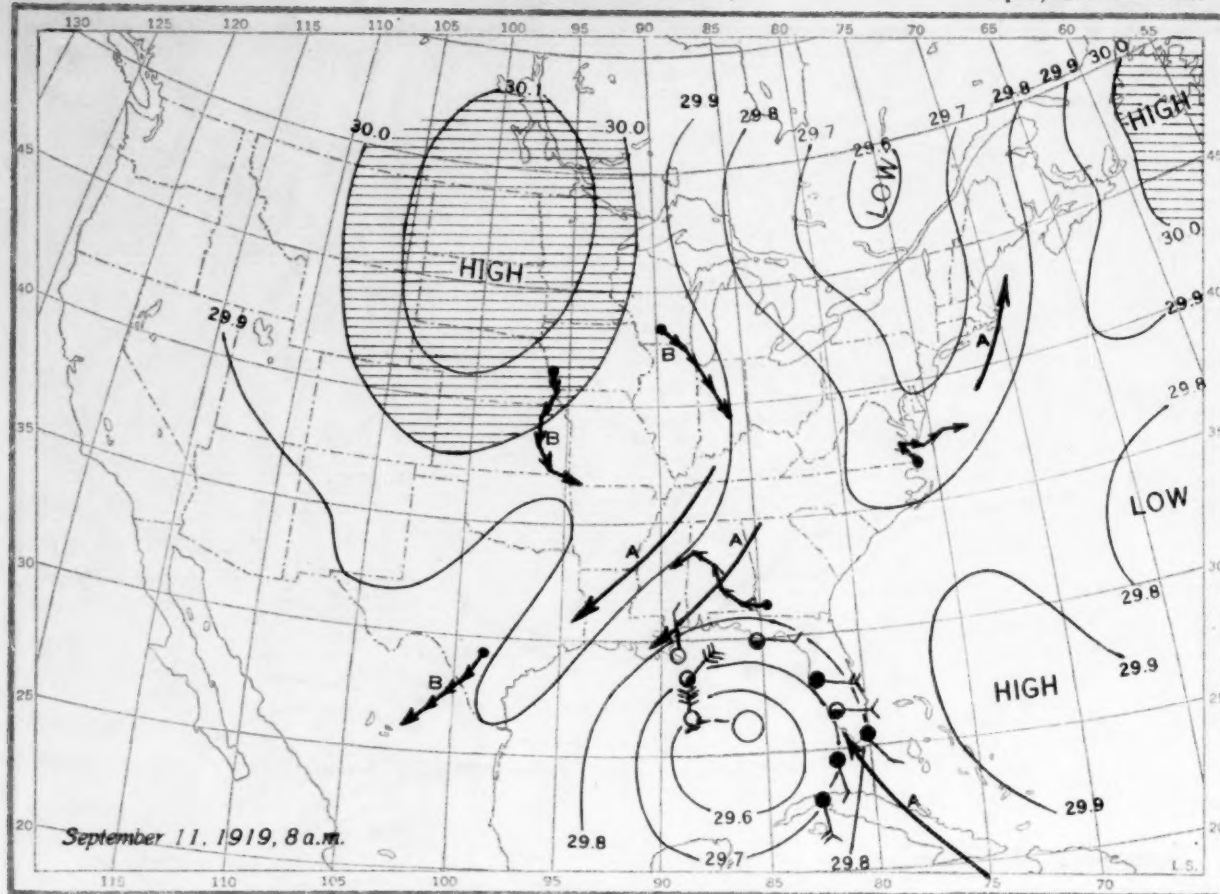
E. H. B. Chart III.

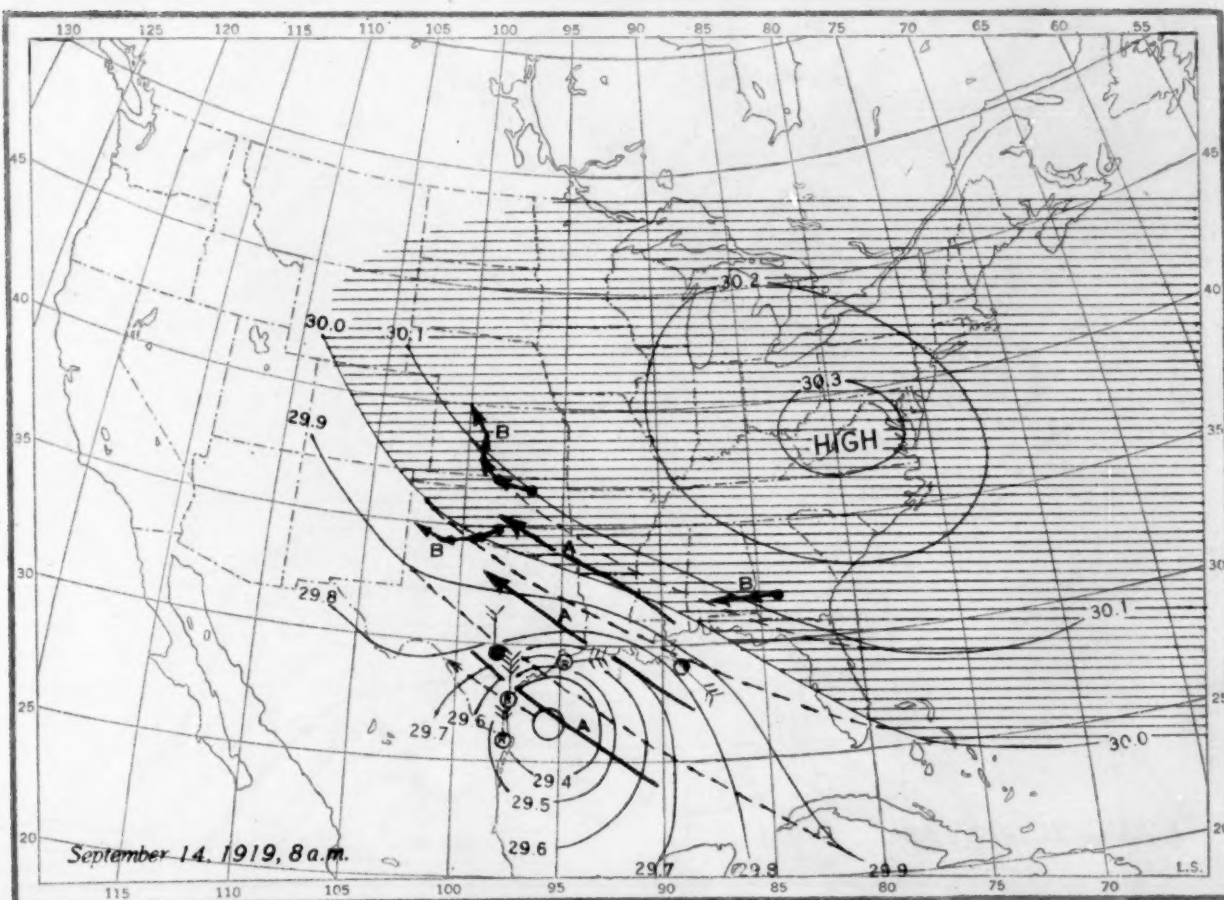
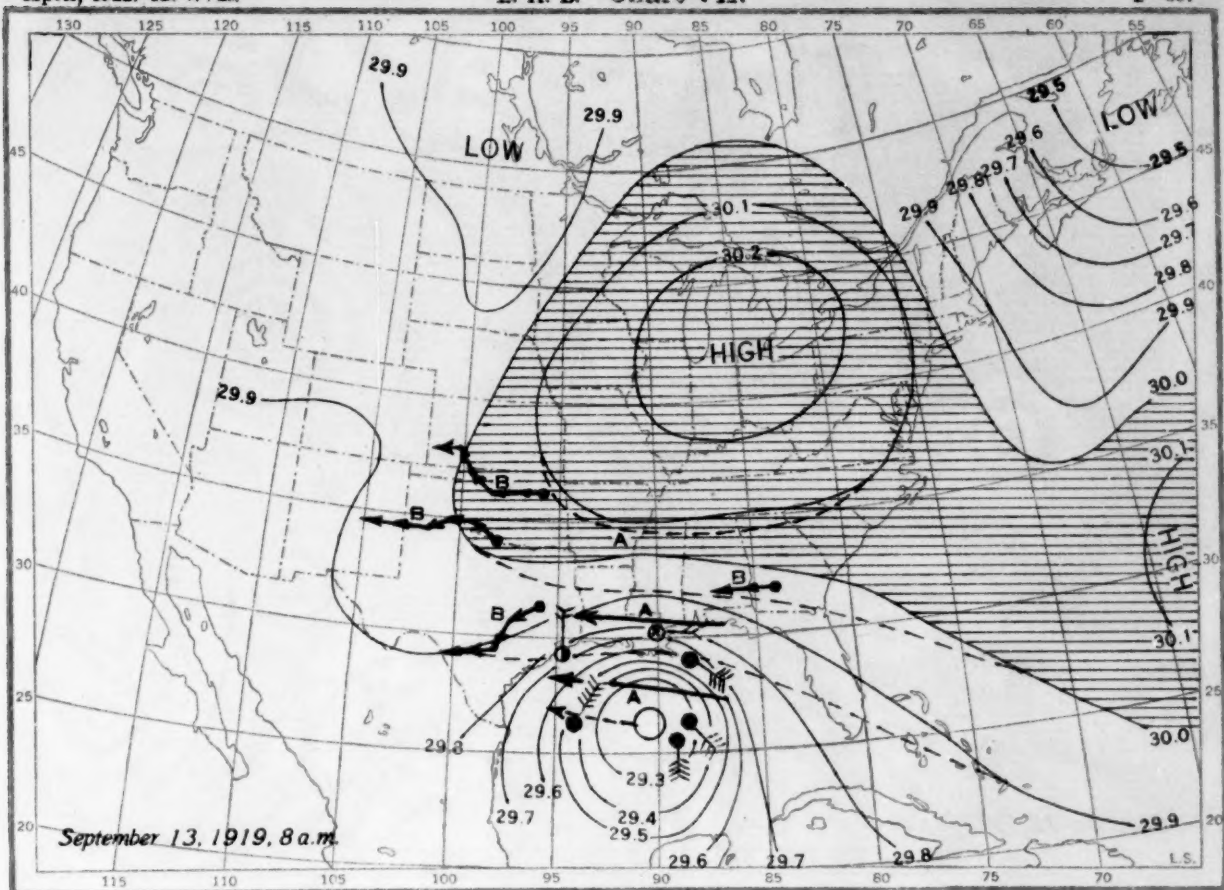
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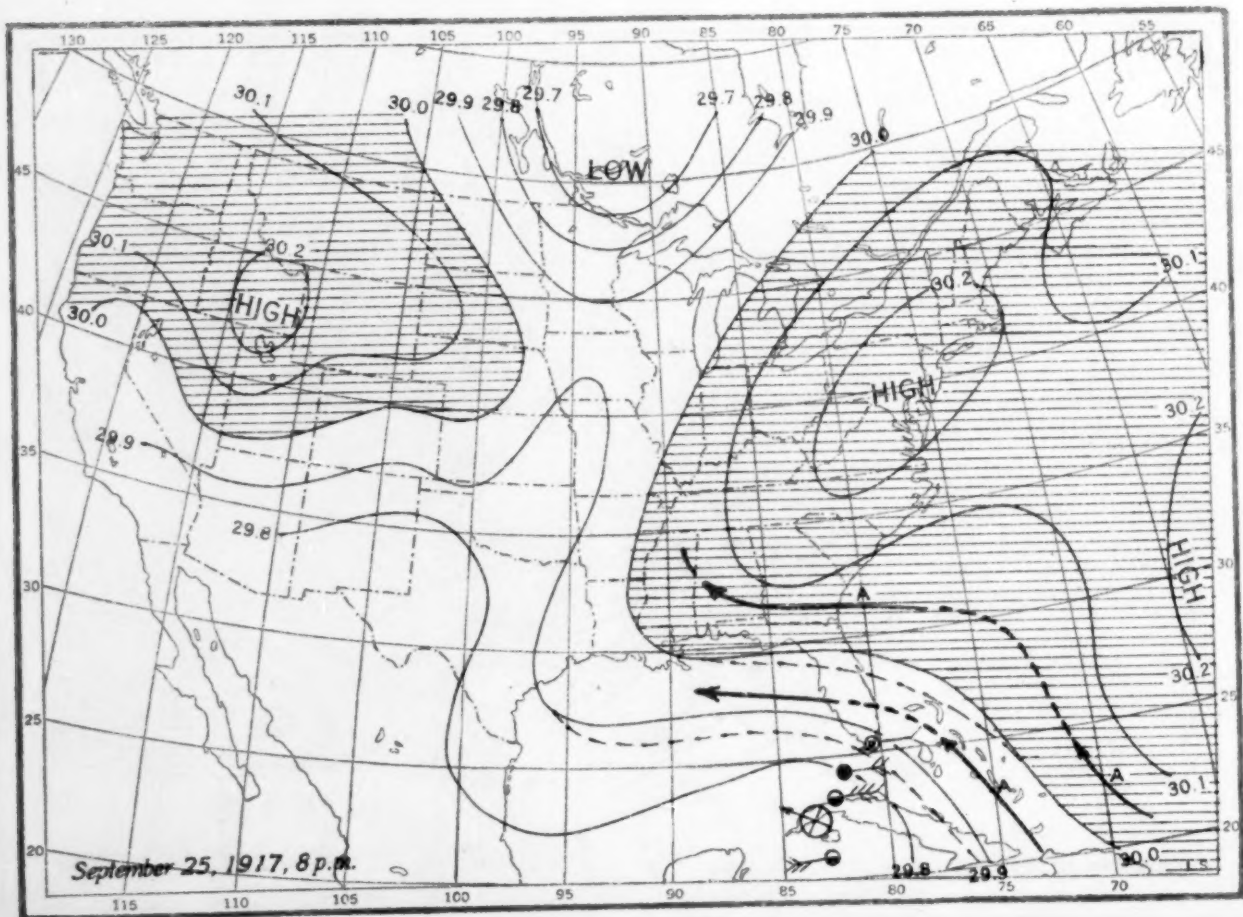
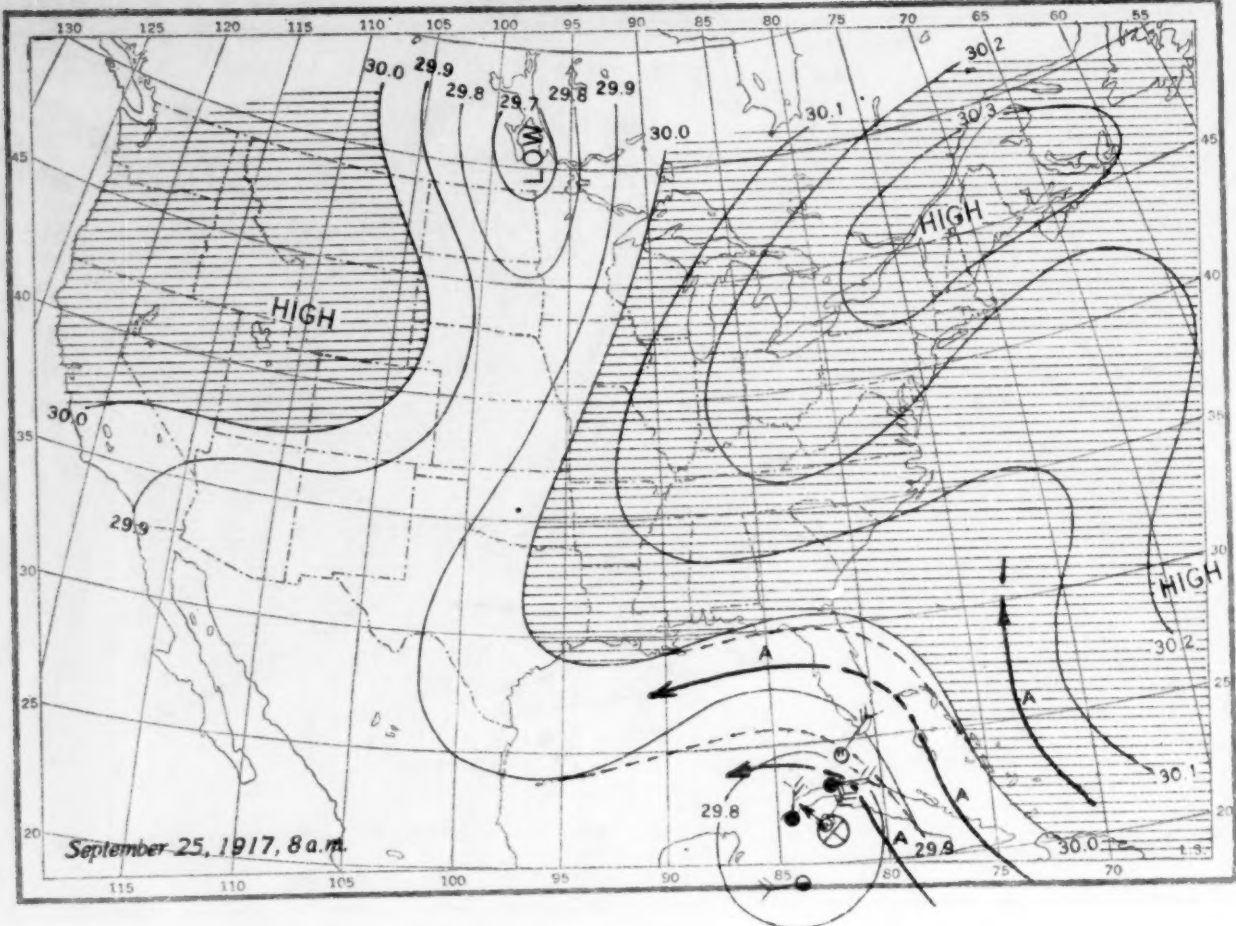


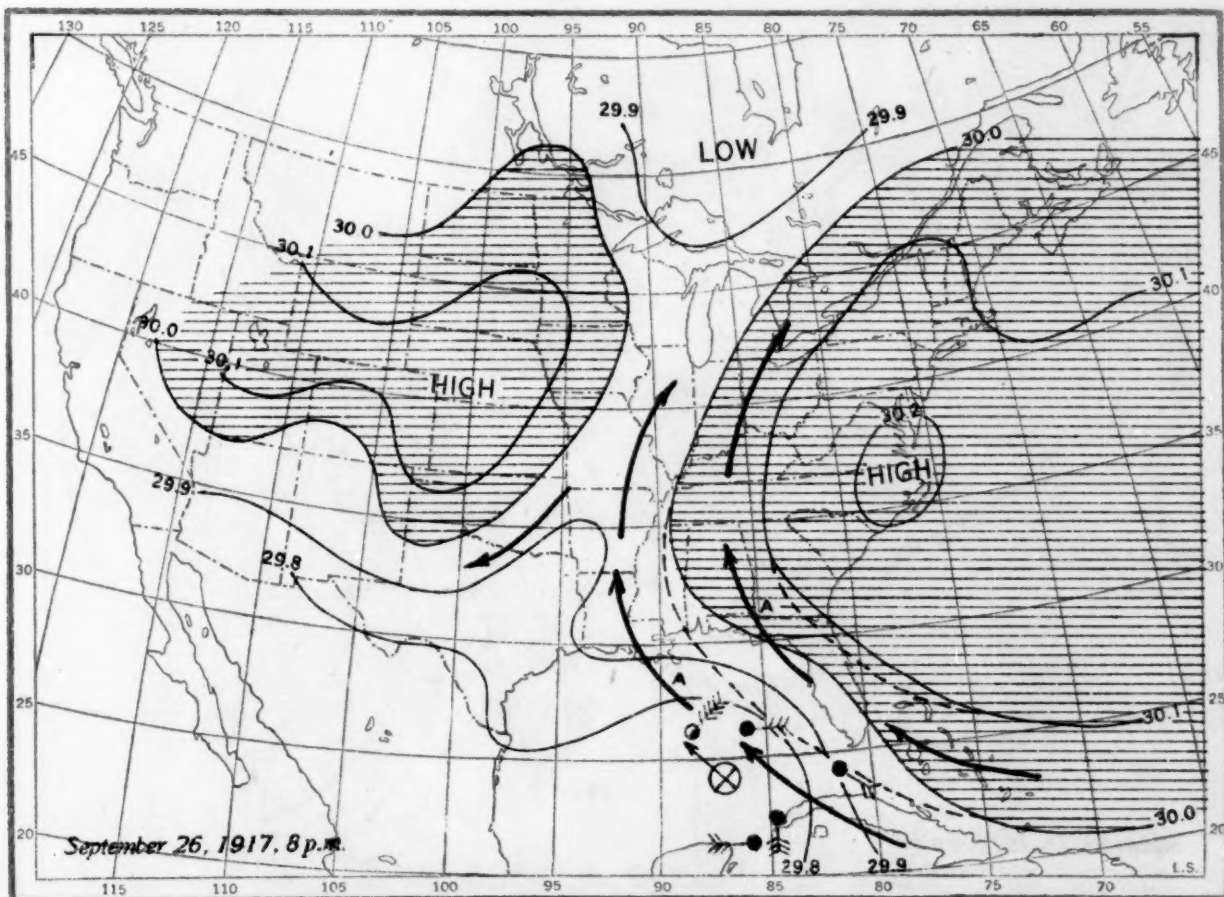
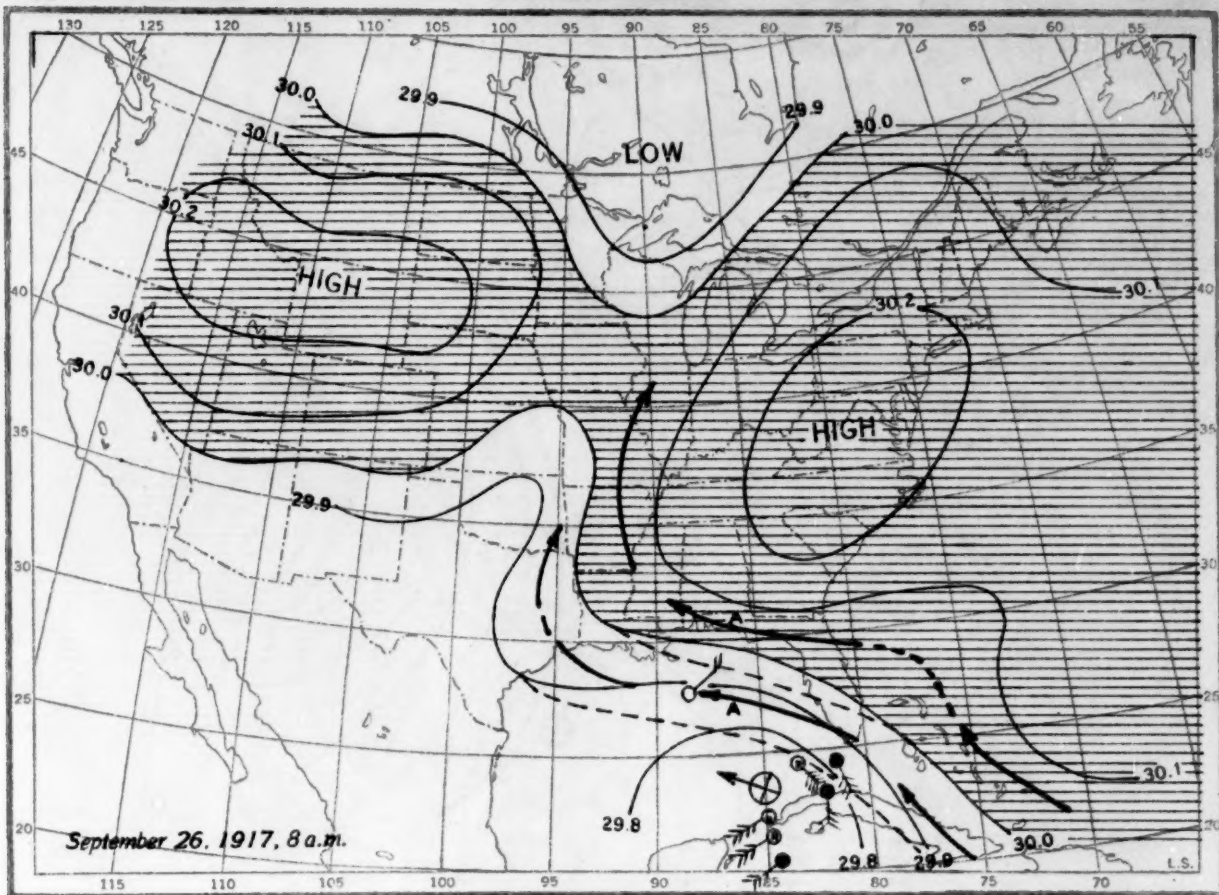


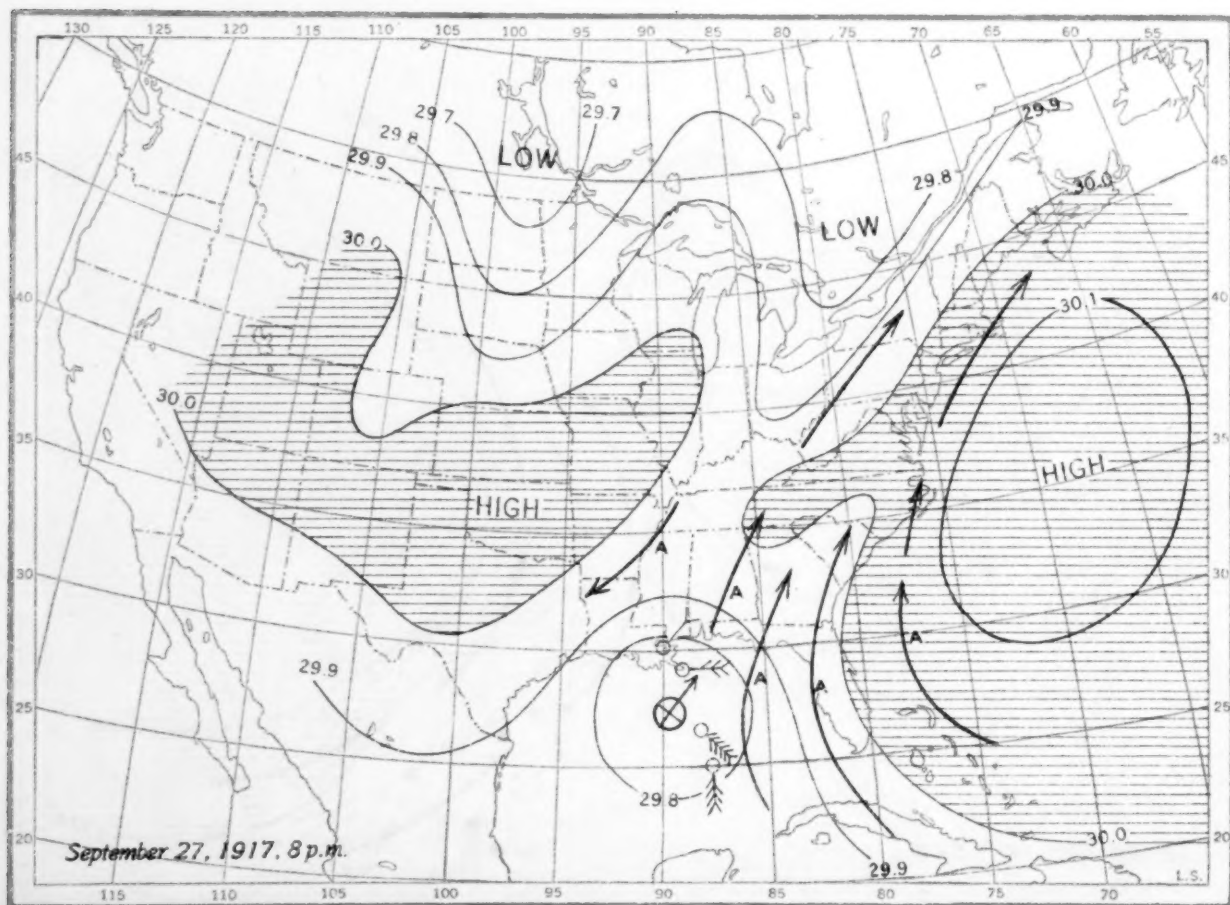
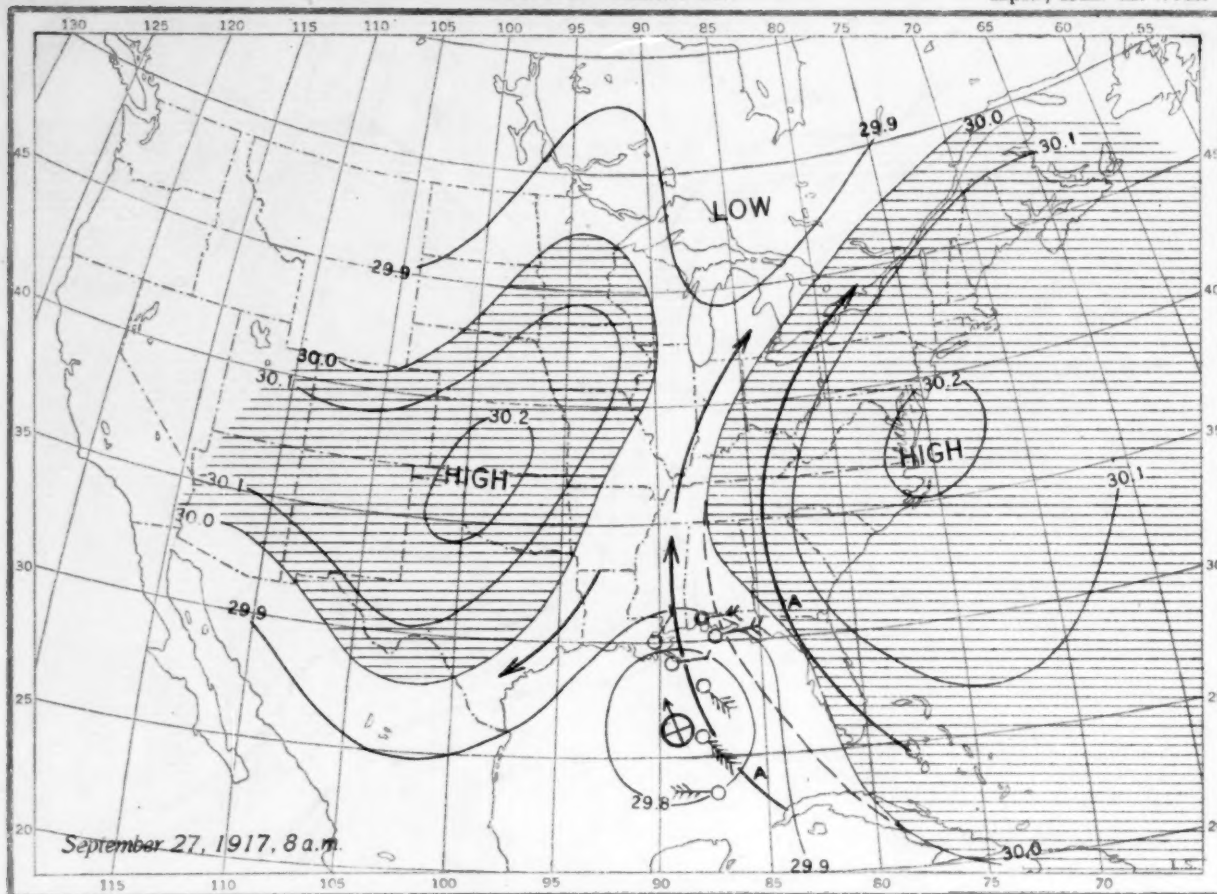


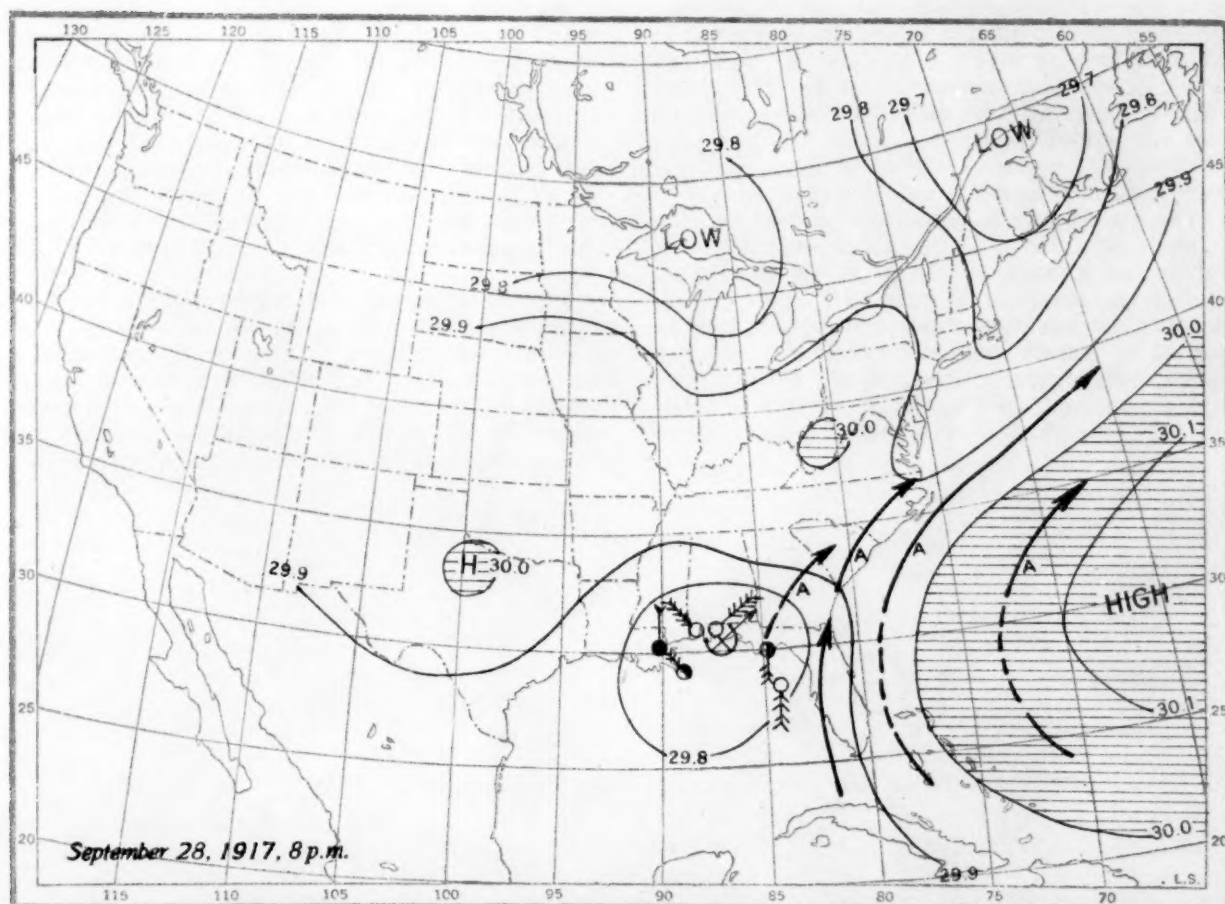
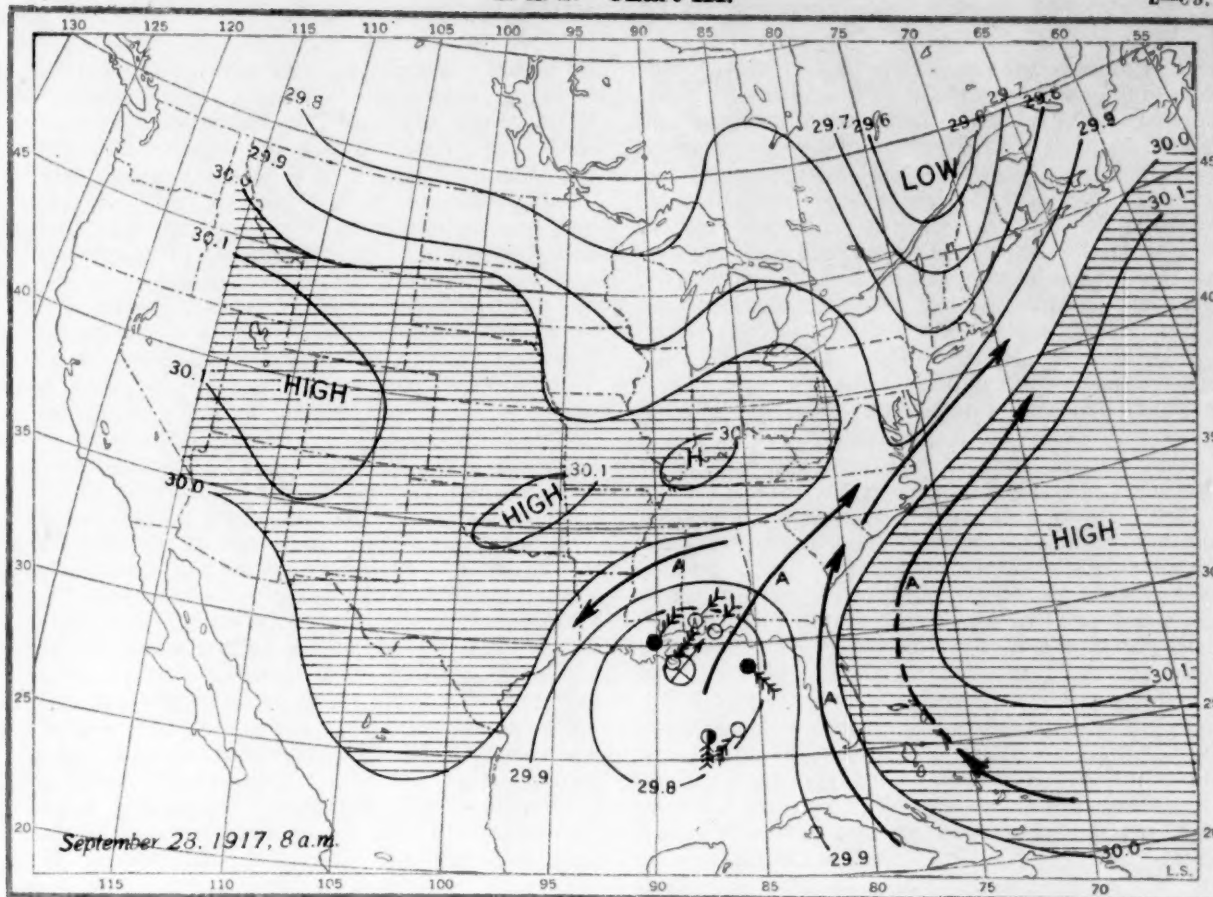














the center of the anticyclone and the general trend of its system of isobars changed these changes were followed by the course of the hurricane. Now the question is: How was this disturbance carried along its track? Disregarding the internal mechanism of the hurricane, are we to assume that the "general drift of the atmosphere" which carried the hurricane onward prevailed over the entire area occupied by the hurricane? Or are we led to assume that the right semicircle of the hurricane was involved in the major wind system flowing along the isobaric system of the adjacent area of high barometric pressure to the northward, and that it was this wind system that carried the hurricane along its course. I rather think this was the case, for it is difficult for me to visualize an eddy of the nature of a hurricane existing in and carried forward in, say, midstream of a wide and deep onward flowing aerial current such as the northeast trades. If we assume that the right semicircle of the hurricane is involved in this major wind system the problem becomes simplified, and at once the source of the power which carries the hurricane onward is seen; also, an explanation is offered of why the winds of the greatest speed are to be found in that semicircle of the hurricane before recurve, where there is a compounding of the cyclonic and anticyclonic wind systems. Where the hurricane is involved in two major wind systems—i. e., when it comes under the influence of the wind system of a traveling anticyclone in addition to the more or less constant wind system of the trades—the resultant of these two systems—considering both their directions and speeds—will presumably determine the direction and speed of movement of the hurricane center.

There are also printed in connection with this paper Charts 7 to 14 of the hurricane of September 7-14, 1919, and Charts 15 to 22 of the hurricane of September 25-28, 1917. Both of these hurricanes were of marked intensity. It will be observed that a reconstruction of the isobars in the immediate vicinity of the hurricane on each of these charts has been attempted—i. e., dotted isobars have been drawn to indicate the probable trend of the isobars had the hurricane not been in existence. Long heavy arrows, marked A, indicate the probable direction of the major wind system along the reconstructed or hypothetical isobars to the northward of the hurricane center. The inner closed isobar indicates the position of the hurricane and the small arrow with broken shaft indicates the movement of the hurricane center in successive periods of 24 hours in the case of the 1919 hurricane and 12 hours in the case of the faster moving hurricane of 1917.

At the time of the occurrence of the hurricane of September, 1919, pilot balloon stations for making upper-air observations of the direction and speed of the wind were in operation at a few points in the South Atlantic and Gulf States. The wind directions observed in the free air above these stations during the 7th to 14th of September, 1919, are indicated, marked B, on these charts. The

base arrow indicates the surface direction, the second arrow the direction of the wind at the 1,000-meter level, the third arrow the direction at the 2,000-meter level, and so on to the 4,000-meter level if that was reached. It will be noted that these upper-air wind directions conform to the hypothetical directions of the wind when they are shown for the same regions. The reader should refer to the MONTHLY WEATHER REVIEW of October, 1919, where he will find a detailed account of the sounding observations made in the Southern States while this hurricane was crossing the Gulf of Mexico. The paper is by Mr. R. Hanson Weightman.

Moreover, the pilot balloon observations made at San Juan, Porto Rico, during and after the approach of the hurricane of September, 1921, show the existence of this wind system, and it was in evidence again in October, 1921, at the Key West, Fla., station when a hurricane passed northward through the Yucatan Channel and thence northeastward to the vicinity of Tampa, Fla. Moreover, the hypothesis explains why in the vicinity of Habana, Cuba, as observed by Father Viñes, when the vortex of a hurricane lies to the south-southeast, the cirrus clouds move from south-southeast, the cirro-cumulus from the southeast, the dense cirrus-veil from the east-southeast, the alto-stratus from the east, the low clouds from the east-northeast, and the wind from the northeast. Here we have the turning to the right as height increases; it seems probable that between 3,000 and 4,000 meters in the right front will be found the wind system that corresponds with the direction of advance of the hurricane center. It is believed that the hurricane, half embedded in the trade-wind system, is carried onward by reason of its being thus situated, and that meteorologists in forecasting the movement of a hurricane must consider this a reasonably well established fact, but when two exterior wind systems—i. e., the trade system and that of a traveling anticyclone—pass through the hurricane area the problem becomes more complicated, but it is believed that under these conditions, the direction and the rate of movement of the hurricane center will become the resultant of the two. In the case of a single area of high barometric pressure, fixed in position and magnitude, there is reason to believe that the course of a hurricane would be a simple one—viz, its center would follow the outer isobar with the speed of the wind system then prevalent.

Now reverting to the statements made concerning the endless variety of shapes of hurricane tracks and their seeming disregard of all physical laws, it would appear that these tracks are not haphazard but conform to the changes that take place in the positions and magnitudes of the areas of high barometer and their attendant wind systems. Hence the endless variety of tracks is but a reflection of the endless variety of the changes in the isobaric systems of these high barometric areas at the times the hurricanes were in progress.

HOURLY PRECIPITATION AT NASHVILLE, TENN.

By ROSCOE NUNN, Meteorologist.

[Weather Bureau, Nashville, Tenn.]

Requests from insurance companies for data to be used in connection with "rain insurance" prompted the writer to compile the information in this article. Questions could have been answered in a general way, though not satisfactorily, without going into these details, but the subject is probably of sufficient general interest to justify careful treatment. The Nashville records no doubt give a fair representation of a considerable district in this part of the country, and probably have some advantages over the data for more northern points for a study of this kind, as the hourly automatic records are more complete for the cold months, snowfall not being automatically registered.

Up to this time data for hourly values of precipitation have been available for only short periods, and even now very few stations have records of hourly values for more than the last 17 years. However, interesting studies of hourly amount and frequency of precipitation were published by Dr. O. L. Fassig, *The Climate of Baltimore*, in volume 2, "Maryland Weather Service," 1907, and by Prof. H. J. Cox and Mr. J. H. Armington, *The Weather and Climate of Chicago*, 1914. In both cases records of a 10-year period were used.

In order to determine whether there exist any marked diurnal periods in amount or frequency of precipitation at Nashville, the hourly values as recorded in Form No. 1014, Daily Local Record, were carefully examined. This station has a good automatic record of precipitation and the hourly amounts are entered on Form 1014, beginning with January, 1905. The records for the years 1905-1921, inclusive, are therefore used, giving a period of 17 years. As only about 2 per cent of the annual precipitation at Nashville is in the form of snow, the automatic record for the entire year could be used, it being deemed permissible to estimate the hourly amounts in cases of snowfall.

In computing the hourly frequency it was thought worth while to prepare data, first, for all occurrences, including traces, and, second, for occurrences of measurable amounts only. This brings out the fact that a large percentage of the records of precipitation are for traces. If we consider all hours having precipitation (including traces), we find that not much more than one-half of the hours have measurable amounts, 0.01 inch or more. In January, hours having 0.01 inch or more are 54 per cent of the total hours with precipitation, and the percentages for the other months are as follows: February, 49; March, 54; April, 58; June, 59; July, 56; August, 58; September, 58; October, 56; November, 56; December, 55. Graphs showing the frequency for all amounts, including traces, and for measurable amounts only, are interesting when compared in that they seem to show that records of traces are more frequently made around the regular morning and evening observation hours than during the busier office hours, or at night. For this and other reasons, the data for frequency of measurable amounts (0.01 inch or more) would seem to be more valuable than the data which include traces.

An explanation of the term "frequency" as used here should perhaps be given. It means simply the number of times precipitation was registered in each hour, expressed in percentage of the possible, and has little to do with the duration of precipitation or with separate occurrences—that is, the number of times precipitation began and ended. If, for example, rain began at 3:45

p. m. and ended at 4:10 p. m., the two hours would be counted as having precipitation, although all of it occurred within 25 minutes. Again, if rain began at 2:30 a. m. and continued until 10:30 p. m., there would be 20 hours with precipitation, although only one period.

The duration of precipitation—actual number of hours rain or snow was falling—has not been compiled for a period of sufficient length to give a satisfactory average, but a single year, 1920, is used to throw some light on this phase of the subject. The year 1920 had nearly the normal amount of precipitation for the year as a whole, and also nearly normal amounts for the four seasons, although several of the monthly amounts differed decidedly from the normal. January, April, and August were unusually wet, while February, March, and November were unusually dry, but the seasonal and annual amounts were nearly normal. Table 1 shows the actual number of hours, also the percentage of the total hours, that precipitation was occurring, for each month of the year 1920.

Year 1920	Duration of precipitation, hours.	Percentage of time precipitation was occurring.	Year 1920.	Duration of precipitation, hours.	Percentage of time precipitation was occurring.
January.....	132.2	17.8	August.....	46.1	6.2
February.....	120.7	17.3	September.....	35.6	4.9
March.....	85.8	11.5	October.....	15.3	2.1
April.....	86.2	12.0	November.....	60.1	9.2
May.....	54.7	7.4	December.....	94.2	12.7
June.....	44.5	6.2	Annual.....	805.8	9.2
July.....	24.4	3.3			

In the beginning traces of precipitation were considered: that is, precipitation was counted as going on no matter how light it might be. Drizzly days cause the duration figures to mount up, although there may not be much precipitation to show for it. Winter months, therefore, have much longer duration of precipitation than do the summer months, which more frequently receive their precipitation mostly in quick, heavy showers. The actual amount of precipitation normally received is only slightly greater in winter than in summer.

From the accompanying tables and charts (tables 1 and 2 and figs. 1-3), showing the hourly amounts in inches and the hourly frequency in percentage of the possible, it may be readily observed that there are no strong diurnal periodicities, either in amount or frequency of precipitation at Nashville. However, two fairly well-defined periods of maxima and two of minima may be discovered in the 24 hours. Considering first the hourly amounts and taking the year as a whole, there is a maximum period which begins to come on about 3 a. m. and culminates about 5 a. m. This is followed closely by a minimum period beginning about 6 a. m. and culminating about 9 a. m. Beginning about 10 a. m., there is an unsteady rise in the amount of precipitation, which continues for several hours and culminates about 4 p. m., and the hour ending at 4 p. m. shows the greatest precipitation of any hour of the day. After 4 p. m. the hourly amounts diminish rather steadily and reach a minimum about 10 p. m. During the midnight hours the precipitation fluctuates somewhat, but these hours belong to a minimum rather than a maximum period.

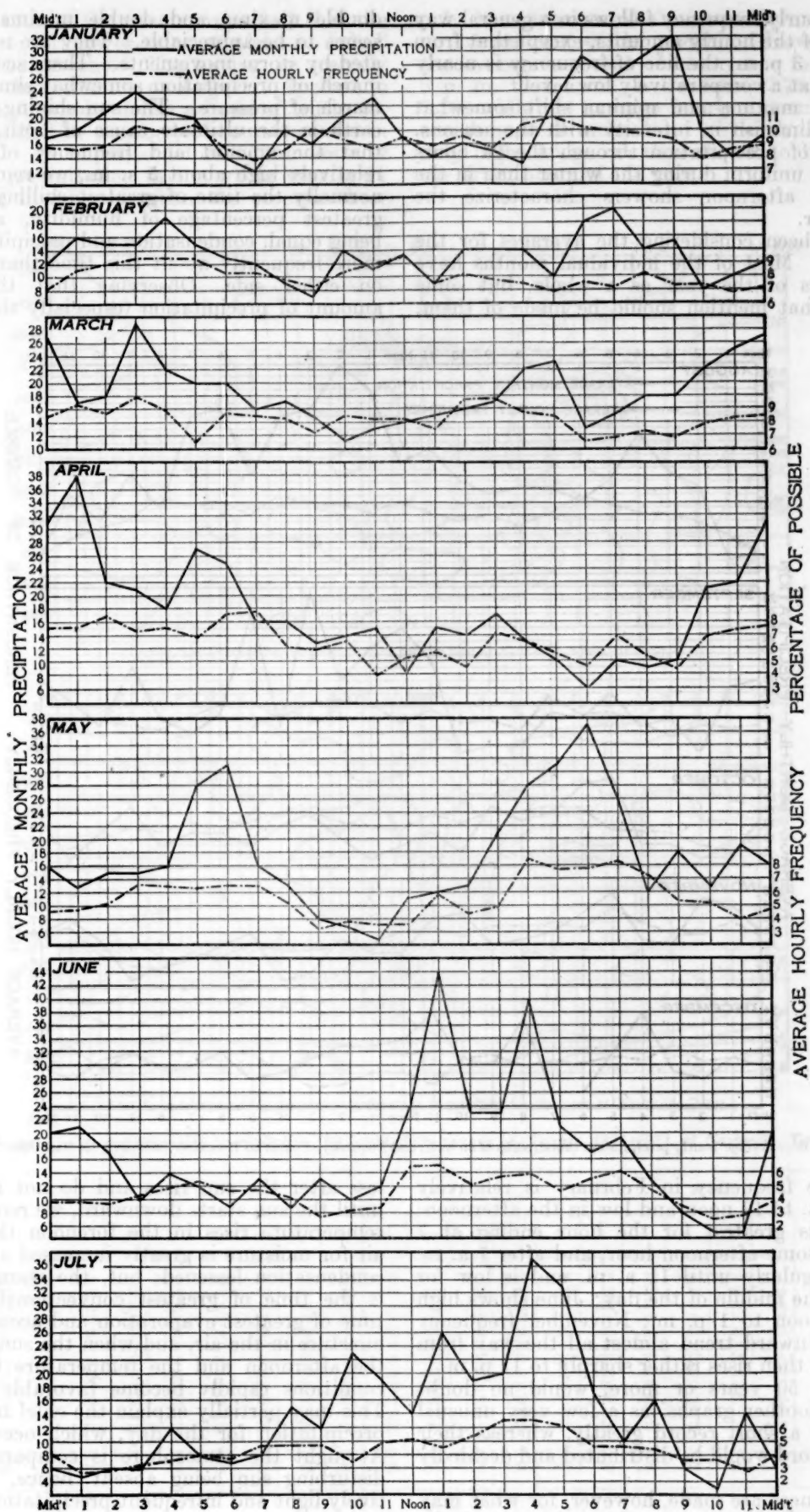


FIG. 1a.—Average hourly precipitation (hundredths of an inch) and frequency, January to July, inclusive, for Nashville, Tenn.

The range of hourly frequency follows in a general way the rise and fall of the hourly amounts, except that from about 12 noon to 3 p. m. the line of frequency is nearly straight, running at a comparatively low level.

The periods of maxima and minima shift somewhat and increase or diminish in intensity with the seasons. The distribution of precipitation through the 24 hours is decidedly more uniform during the winter than in the summer. Heavy afternoon showers characterize the records in summer.

We have just been considering the averages for the year as a whole. Most of the individual months have the characteristics of the year as a whole, but some differ so widely that mention should be made of them.

double maxima and double minima in the 24 hours seems to be appreciable. They are not entirely obliterated by storm movements. There seems to be a diurnal march of precipitation somewhat similar to the diurnal march of pressure. The sun shining upon the rotating earth is the ultimate cause of both. Noting the fact that the amount and frequency of precipitation are relatively high about 5 a. m., we remember that this is normally the time of greatest chilling of the air and of greatest percentage of humidity, and, other things being equal, condensation and precipitation should occur more frequently about this time than during the hours on either side. Observing that the frequency and amount of precipitation (especially the frequency) grow

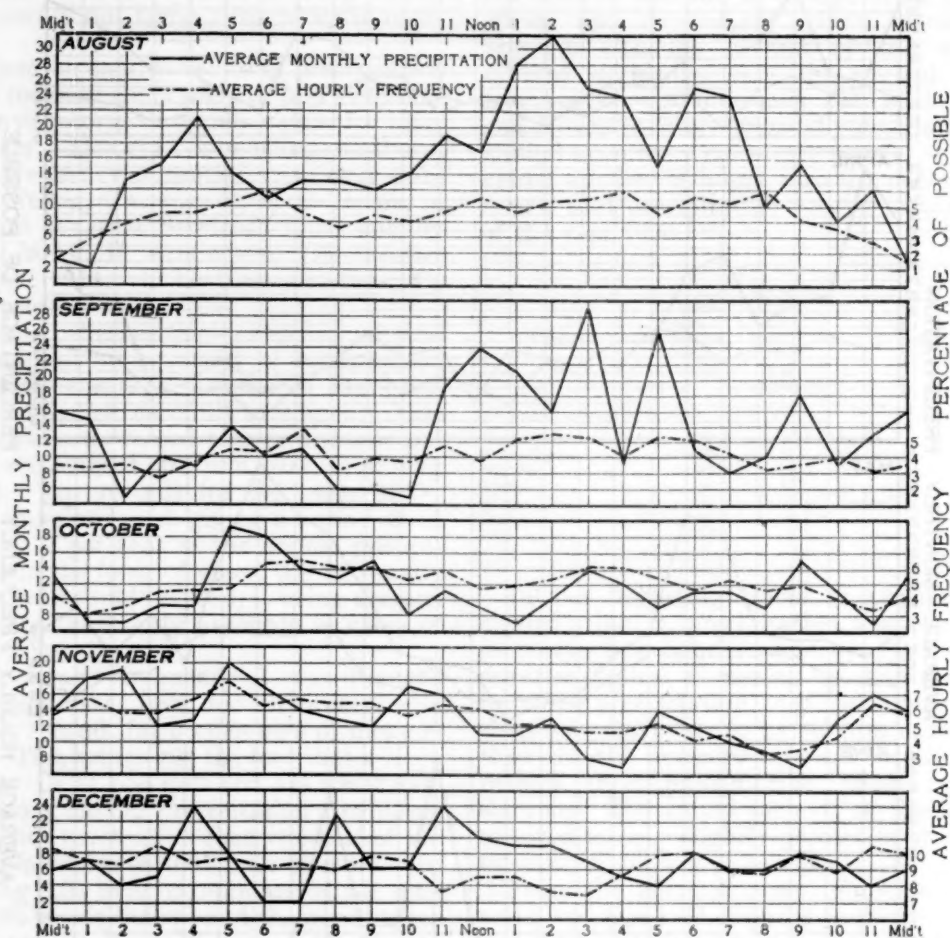


FIG. 1b.—Average hourly precipitation (hundredths of an inch) and frequency, August to December, inclusive, for Nashville, Tenn.

For example, the frequency in February is relatively high from 10 a. m. to 12 noon and low in the afternoon; April frequency is greatest for the hour ending at 7 a. m., instead of some afternoon hour, and after 7 a. m. it diminishes irregularly until 11 a. m. and is low for several hours in the middle of the day; June shows high frequency from noon to 1 p. m.; November frequency shows a slow downward trend almost all the way from 5 a. m. to 8 p. m., then rises rather sharply to 11 p. m.

A long record, 50 years or more, would no doubt produce much smoother graphs, as a few very unusual occurrences affect a short record greatly, whereas their effect in a long record would be distributed and decidedly modified.

After all allowances are made, however, for what may be called accidental occurrences, the existence of the

less after the sun rises and do not increase materially until the sun starts downward, we remember that as the temperature rises in the forenoon the capacity of the air for moisture is greatly increased and the chances for condensation lessened; but, the warm part of the day is the time of greatest convectional activity and the time of greatest evaporation and accumulation of actual moisture in the air, and when the sun loses his power in the afternoon and the temperature begins to fall, the conditions rapidly become favorable for condensation. This may partially explain the chief maximum period of precipitation for the day, which occurs about 4 p. m. At night the atmosphere is comparatively stable, the disturbing sun being absent; hence, there is comparatively light and infrequent precipitation.

It is interesting to note (but not unexpected) that the saying in Tennessee, "It never rains at night in July," is only partially borne out. The saying is scarcely more true of July than of June or August. Applied to the warm season as a whole, it has a basis of truth, for the most of the rainfall in summer, of course, comes in afternoon showers. As a matter of fact, the hour of least frequency of precipitation in the whole year is 11 p. m. to midnight in August, when the records show

only 8 occurrences of a measurable amount in 17 years, or 1.5 per cent of the possible. However, to be exact, the average per cent of occurrence for the night hours, 8 p. m. to 4 a. m., is, in June, 7.75; July, 7; August, 7.50; while the average hourly amounts for those hours are, June, 0.12 inch; July, 0.07 inch; August, 0.11 inch. July night hours are thus shown to be, on an average, the driest hours of the year.

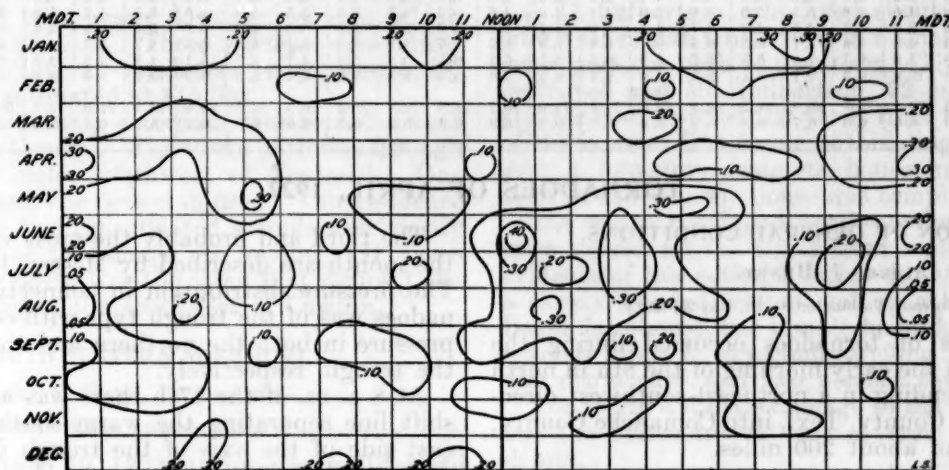


TABLE 2.—Average hourly frequency of precipitation at Nashville, Tenn. (percentage of possible), 1905-1921, inclusive.

Months.	A. M.												P. M.											Surf.	
	1	2	3	4	5	6	7	8	9	10	11	Noon.	1	2	3	4	5	6	7	8	9	10	11		Mid'l.
January.....	8.7	8.9	10.4	9.9	10.4	8.7	7.8	8.5	10.1	9.3	8.7	9.5	8.9	9.5	8.7	10.4	11.0	10.2	9.9	9.7	9.3	7.8	8.5	8.9	9.3
February.....	8.5	9.0	9.4	9.4	9.4	8.3	8.3	7.7	7.3	8.3	9.0	9.4	7.5	8.1	7.7	7.5	6.9	7.5	7.1	8.1	7.3	7.3	6.7	7.1	8.0
March.....	9.3	8.7	9.9	8.9	6.5	8.7	8.4	8.2	7.2	8.4	8.2	8.2	7.4	9.7	9.7	8.7	8.4	6.5	6.8	7.2	6.8	7.8	8.2	8.4	8.2
April.....	7.6	8.4	7.3	7.6	6.9	8.6	8.8	6.1	5.9	6.5	3.9	5.1	5.7	4.5	7.1	6.5	5.5	4.5	6.9	5.3	4.3	6.9	7.3	7.6	6.4
May.....	4.7	5.1	6.6	6.5	6.3	6.5	6.5	5.1	3.2	3.8	3.6	3.6	5.9	4.4	4.9	8.5	7.8	7.8	8.2	7.2	5.3	5.1	4.0	4.6	5.6
June.....	3.9	3.7	4.3	4.9	5.3	4.7	4.7	4.1	2.7	3.1	3.3	6.5	6.5	5.1	5.7	5.9	4.7	5.5	6.1	4.7	3.5	2.5	2.7	3.9	4.5
July.....	2.7	2.8	3.2	3.6	4.0	3.8	4.7	4.7	4.7	3.4	4.9	5.1	4.6	5.3	6.5	6.5	6.1	4.6	4.6	4.4	3.6	3.6	2.8	4.0	4.3
August.....	2.8	3.8	4.6	4.6	5.3	5.9	4.6	3.6	4.4	4.0	4.6	5.5	4.7	5.3	5.5	5.9	4.6	5.5	5.3	5.9	4.2	3.6	2.7	1.5	4.5
September.....	3.3	3.5	2.7	3.7	4.5	4.3	5.7	3.1	3.9	3.7	4.7	3.7	5.1	5.5	5.3	4.1	5.3	5.1	4.3	3.3	3.5	3.9	3.1	3.5	4.1
October.....	3.0	3.4	4.4	4.6	4.7	6.3	6.5	6.1	6.1	5.3	5.9	4.7	4.9	5.3	6.1	6.1	5.5	4.7	5.3	4.7	4.9	4.0	3.4	4.2	5.0
November.....	6.7	5.9	5.9	6.7	7.8	6.3	6.7	6.5	6.5	5.7	6.3	6.1	5.1	5.1	4.7	4.7	5.1	4.1	4.5	3.3	3.5	4.3	6.3	5.9	5.6
December.....	9.5	9.3	10.4	9.3	9.7	9.1	9.3	8.9	9.7	9.5	7.6	8.4	8.5	7.6	7.4	8.5	9.9	10.1	8.9	8.7	9.9	8.9	10.4	10.2	9.2
Sums.....	70.7	72.5	79.1	70.7	80.8	81.2	82.0	72.6	71.7	71.0	70.7	75.8	74.8	75.4	79.3	83.3	80.8	76.1	77.9	72.5	66.1	65.7	60.1	69.8	74.7
Means.....	5.9	6.0	6.6	6.6	6.7	6.8	6.8	6.0	6.0	5.9	5.9	6.3	6.2	6.3	6.6	6.9	6.7	6.3	6.5	6.0	5.5	5.5	5.5	5.8	6.2

TORNADOES OF APRIL, 1922.

DISCUSSION OF GENERAL CONDITIONS.

ALFRED J. HENRY.

[Weather Bureau, Washington, C. D., May 25, 1922.]

Three outbreaks of tornadoes occurred during the month, the first on the early morning of the 8th in north central Texas, extending in a northeast-southwest direction from Runnels County, Tex., into Comanche County, Okla., a distance of about 200 miles.

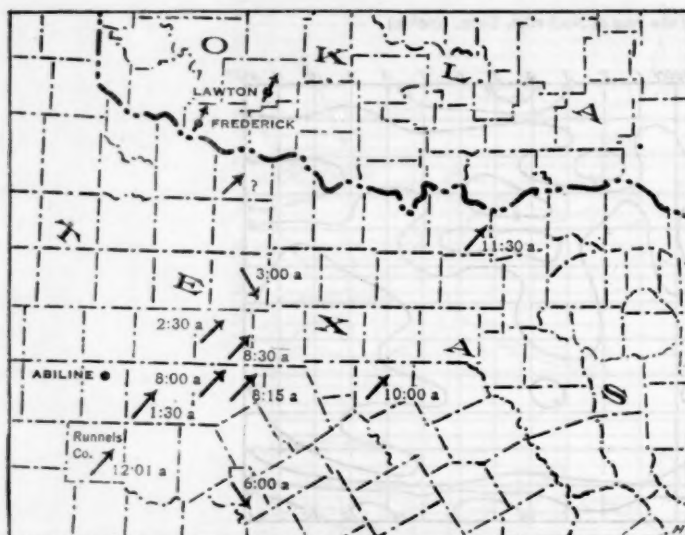


FIG. 1.—Region of tornado occurrence in Texas and Oklahoma, Apr. 8, 1922.

The exceptional character of this outbreak was the fact that practically all of the storms developed after midnight of the 7th. In the absence of detailed field data it is impossible to determine whether there was one general storm of long duration or a group of local manifestations of tornadic activity in the path of the main cyclone. The latter, after 24 hours' stagnation over Texas, moved rapidly during the 24 hours ending 8 a. m., 9th, to the upper Mississippi Valley, where it was centered as a circular storm of wide extent and low central pressure—29.00 inches. Another rather unusual circumstance in connection with this cyclonic storm was the fact that it was almost immediately followed by another, likewise of low barometer level at its center—viz. 29.30 inches at Dodge City, Kans., on the morning of the 10th.

This storm or cyclonic depression gave rise to the second outbreak of tornadic storms in southwestern Missouri, as described by Meteorologist W. B. Hare in the following pages.

The third and probably the most violent tornadoes of the month are described by Messrs. Root and Shipman. The pressure distribution in connection with these tornadoes was of the trough type with centers of minimum pressure in both the northern and the southern ends of the trough, respectively.

At 8 a. m. of the 17th there was a well-marked wind shift line separating the warm southerly winds on the east side of the axis of the trough from the relatively cooler north winds on the west side. In the succeeding 24 hours cool northerly winds swept over the region of warm southerly winds in which the tornadoes had their origin.

In all 42 persons were killed and 237 injured in these storms. The property loss was estimated as \$968,150.

The foregoing does not include loss of life or property in Ohio, as reported by Meteorologist W. H. Alexander. See page 187.

IN TEXAS.

B. BUNNEMEYER, Meteorologist.

[Weather Bureau, Houston, Tex.]

Table 1 gives a summary of the tornadoes that occurred in Texas during April so far as reported to the section center. The property loss amounted to \$232,150, and 14 persons were killed and 108 more or less seriously injured by these storms. All but one of the 11 tornadoes occurred on the 8th.

Special attention is invited to the hours of occurrence which varied between 12:01 a. m. and 11:30 a. m. The length of their paths could not be ascertained, but it is probable that in one or two instances the same tornado passed into an adjoining county. Figure 1 shows the approximate paths followed by the tornadoes. The hour of occurrence has been added to show possible connection between some of the tornadoes charted separately.

TABLE 1.—Tornadoes in Texas during April, 1922.

Locality.	County.	Date and hour of occurrence.	Direction of movement.	Width of paths (feet).	Property loss.	Number persons injured.	Number persons killed.
Goldthwaite...	Mills.....	4th, 6.00 a. m.	nw. to se.	20	\$8,150	0	0
Rowena.....	Runnels...	8th, 12.01 a. m.	sw to ne...	55,000		52	7
Cisco.....	Eastland..	8th, 8.00 a. m.	sw to ne...	33	25,000	3	0
Ranger.....	Callahan..	8th, 8.15 a. m.	sw to ne...	440	6,000	2	0
Opalin.....	Stephens..	8th, 1.30 a. m.	sw. to ne.		15,000	30	5
Caddo.....	Young.....	8th, 8.30 a. m.	sw. to ne.	100	50,000	6	0
Breckenridge..	Stephens..	8th, 2.30 a. m.	sw. to ne.		2,000	2	0
Graham.....	Johnson..	8th, 3.00 a. m.	nw. to se.	120	10,000	1	0
Cleburne.....	Wichita...	8th, 10.00 a. m.	sw. to ne.	440	25,000	1	1
Electra.....	Grayson...	8th, 11.30 a. m.	sw. to ne.	100	25,000	10	1
Whitewright..	Grayson...	8th, 11.30 a. m.	sw. to ne.	500	11,000	1	0
Total.....					232,150	108	14

IN OKLAHOMA.

J. P. SLAUGHTER, Meteorologist.

[Weather Bureau, Oklahoma, Okla.]

A tornado occurred at Lawton, Comanche County, Okla., at about 7:15 a. m. April 8, 1922. The storm moved from the southeast to the northwest¹ and a funnel-shaped cloud was noted. The storm moved through the western outskirts of the town, its path being from two to three blocks in width. The storm was preceded and followed by a heavy downpour of rain, which continued until 9:30 a. m. Three persons were killed and 18 injured. Several residences were destroyed. Total damage was estimated at \$15,000.

Early the same morning a tornado was reported near Frederick, Tillman County. The storm path was through a farm district 5 miles southwest of Frederick. One person was killed and one person injured. One residence was destroyed and two consolidated schools were partly wrecked. Details as to damage are missing. It seems probable that this storm was the same that struck Lawton, Frederick lying to the southwest of Lawton.

IN SOUTHWESTERN MISSOURI.

WALTER B. HARE, Meteorologist.

[Weather Bureau, Springfield, Mo.]

At 7 a. m. on April 10, 1922, an intense, well-formed circular area of low pressure (cyclone) appeared over Nebraska, western Iowa, western Missouri, western Arkansas, Oklahoma, northern Texas, and eastern Colorado. Concordia, Kansas, reported the lowest barometric pressure, 29.26 inches reduced to sea level. Tornadoes most frequently occur in the southern or southeastern portion of cyclonic areas and from 200 to 800 miles from their centers. Southwestern Missouri was about 300 miles southeast of the storm center and a tornado made its appearance about five miles west of Miller, a village in Lawrence County, Missouri, about 35 miles due west of Springfield.

Miller.—William Boyd's house about five miles west of Miller, was demolished shortly before 9 a. m. Two of the inmates suffered severe injury. The roofs of many houses in Miller were swept away and a number of barns destroyed. Rain was falling at the time of the passage of the tornado, the characteristic low hanging black cloud was seen and a loud roaring noise was heard. The tornado came from the southwest and moved toward the northeast.

Ash Grove.—From Miller the storm moved northeastward until it reached Ash Grove, a distance of about 21 miles N. 60° E. The passage of the tornado from Miller to Ash Grove was marked by uprooted and by twisted trees, but the northeastern corner of Lawrence County is sparsely settled and not much damage was done until the tornado passed into the northwestern corner of Greene County. This section was visited by the writer about seven hours after the passing of the storm and the typical destruction of the tornado was clearly visible. The width of the path of destruction was from one-eighth to one-quarter of a mile. Reliable observers at Ash Grove report that rain fell steadily and heavily during the passage of the tornado, that a terrific roaring sound accompanied it, that a violet-colored² funnel-shaped

cloud descended from the sky to the earth, touching the earth in places, then ascending 15 to 20 feet, then touching the earth again; that the path of the tornado cloud was not in a straight line but zigzag, moving in the general direction of northeast; that no hail accompanied the storm; that the funnel cloud sucked into itself roofs, haystacks, houses, cattle, and mules; and that only moderate winds were blowing a quarter of a mile from the funnel cloud. "It moved slower than a train, and made more noise than 50 trains."

J. D. Culbertson, who lived about three quarters of a mile west of Ash Grove, was in a small frame outbuilding directly in the path of the storm. The house was totally destroyed and Mr. Culbertson, 72 years old, was killed and his body carried 100 yards from the original position of the house. The frame outbuilding was lifted entirely over a two-story concrete house near it. The upper story of the concrete house was completely demolished.

The storm continued north-northeast, and is said to have sucked up the water from a stream, although the evidence of this action is rather doubtful; passed through a closely wooded section and up a hill, demolished the Baker farmhouse, one inmate being killed and two others severely injured. A second dwelling in this neighborhood was demolished and two persons severely injured.

The storm did little damage to the town of Ash Grove, but the Frisco tracks were covered with wreckage and debris.

The storm moved thence to the north-northeast, passing Phenix with but little damage. It passed within 2 miles of Walnut Grove and lifted the house from around the family of Marshall Dodd, near Walnut Grove, leaving them sitting as they were before the storm struck. From Phenix the tornado took a more easterly path and struck Harold, a village about 17 miles northeast of Ash Grove.

Harold.—At Harold two blacksmith shops, two dwellings, and a schoolhouse were totally destroyed and several persons received minor injuries. The property loss here amounted to several thousand dollars. All the scholars in the schoolhouse followed the teacher's orders and prostrated themselves upon the floor until the storm passed. The schoolhouse was wrecked, but no one was injured. The tornado next struck Luck, due northeast of Harold a few miles.

Luck.—At Luck two dwellings were totally destroyed, and the schoolhouse was blown to pieces. This was shortly after 9 o'clock. School had been in session but a short time when the storm struck Luck.

As the schoolhouse began to sway before the fury of the storm, the teacher braced herself against the door and instructed the children to prostrate themselves upon the floor. Twice the west end of the building was lifted from the foundation and the windows were shattered by flying timbers. The third onslaught of the wind totally demolished the building and hurled the teacher and the children several feet from the building, severely injuring Eva Nail, 7 years old, who died from her injuries.

Morrisville, in the south central part of Polk County, reported some slight damage from the tornado. It evidently died away near that point. Morrisville is 7 miles N. 15° E. from Luck. The total length of the tornado's path was about 49 miles from Miller to Morrisville.

Property was damaged to the probable extent of \$100,000.

¹ In a later communication Mr. Slaughter reports the most probable direction as being north-northeast.—EDITOR.

² Statement made by three persons evidently without collusion.—EDITOR.

IN ILLINOIS.

By CLARENCE J. ROOT, Meteorologist.

[Weather Bureau, Springfield, Ill.]

Destructive tornadic storms occurred in Illinois on April 16-17, and in Indiana on the 17th, causing in Illinois 7 deaths, the injury of 53 persons, and property losses estimated at \$295,000. The 7 p. m. weather map of April 16 shows a center of low barometer (29.46 inches) at Amarillo, Tex. At 7 a. m. of the 17th the principal center (29.48 inches) had moved to Toledo, Ohio, with secondary centers in Missouri and northern Illinois. At that time the winds were northerly in the northwest part of the State and southerly in the other areas, with all stations reporting thunderstorms during the night. The rainfall exceeded 2 inches at St. Louis and Terre Haute. By the evening of the 17th the center of disturbance had moved to Lake Huron. Illinois was directly in the path of the low pressure area.

The first tornado had its inception near Oakdale Washington County, probably about 11 p. m. of the 16th. It moved due northeast in a remarkably straight line across Washington County, passing through the extreme northwest corner of Jefferson County, then through Marion, Clay, Effingham, southeast corner Jasper, and Clark Counties, ending near the Indiana line about 6 miles west of Terre Haute.¹ From reports received it is evident that the storm passed through Washington, Jefferson, and Marion Counties during the hour preceding midnight of the 16th. It appeared in Jasper County in the hour immediately following midnight, and then moved on across Clark County. There was ample evidence of true tornadic action. The width of the path of destruction varied considerably, but as a rule was less than 600 feet.

The first damage occurred at Nashville, where a power house was unroofed, a number of trees were uprooted, and there was considerable damage of a minor nature. The storm moved on to Irvington, doing some damage before reaching the town. The public school, about six residences, and many outbuildings were destroyed, and several business buildings and a number of residences were badly damaged. The losses in Washington County are estimated at \$100,000. The tornado then passed into the northwest corner of Jefferson County, damaging and destroying farm homes and properties in its passage. A church and school were destroyed in Jefferson County. The path then led through Marion County, where damage totaling \$14,000 was sustained.

An infant was killed at Irvington, and three lives were lost in the country east of the town. About 15 persons were injured in Irvington and in the country adjoining. In the next 40 miles of its course the destruction was rather limited, perhaps due to the storm lifting at times. The losses in Clay County were estimated at but \$2,000. There was damage at one farm place in Effingham County, and in the western part of Jasper County a barn was demolished and a house was unroofed. Severe damage began again at the edge of Rose Hill, Jasper County. The tornado then moved northeast through the country, damaging and destroying farm properties. In Jasper County two rural churches and at least three homes were completely destroyed, other residences were damaged, and much other property was damaged or destroyed. One man was killed in this neighborhood. One person reports the approach of the tornado as "an onrushing, roaring mountain of inky blackness, light beneath, accompanied by constant flashes of lightning." A correspondent reports the following freaks of the storm:

¹ About 130 miles.—Editor.

Pieces of timber were stuck in the ground like fence posts; shingles and straws were sticking into trees; a piece of 2 by 4 was found imbedded several inches in a tree; roofs of some buildings were carried more than a mile; poultry surviving the storm were practically destitute of feathers; ends were blown out of houses, but pictures were left hanging on the walls in the same buildings; trees nearly 2 feet across were twisted off close to the ground; in many places grass growing in the fields was blown away and the ground left bare; many frail buildings directly in the tornado's path were left standing, while strong buildings nearby were completely wrecked; adjoining trees and buildings were blown down in opposite directions; in some buildings they seemed to explode outward as if caused by the internal pressure of the air.

In Jasper County there was one death, 10 persons were injured, and the property loss was \$50,000. The storm moved diagonally across Clark County, through the rural sections, injuring 10 persons in that county and inflicting a loss to property estimated at \$88,000. This tornado caused the death of 5 persons, the injury of 47, and an estimated property loss of \$275,000.

Another tornado occurred in the afternoon of April 17, being first seen just northwest of Odgen in the eastern part of Champaign County at about 3:30 p. m. It moved east through Fithian at 3:45 p. m., then curved northeastward, and passed 3 miles to the southward of Bismarck about 4 p. m. This storm crossed Vermilion County and passed into Indiana, being confined entirely to rural districts until it struck the town of Hedrick in Indiana. It appears that the tornado crossed Indiana and moved some distance into Ohio. All reports indicate the presence of a funnel-shaped cloud. It is probable that the tornado lifted at times, as there were places in its path where no damage was reported. The tornado traveled across country at a rate of about 40 miles per hour, this being the velocity of translation of the Mattoon tornado of May, 1917. At Odgen and Fithian the width of the path of great destruction was reported to be 250 to 300 feet. In Champaign County there were two deaths, and five persons were injured, the deaths occurring 2 miles north of Odgen. One person was injured in Vermilion County. A conservative estimate of the property loss from this storm, in Illinois, is \$20,000.

IN INDIANA.

TRUMAN G. SHIPMAN, Meteorologist.

[Weather Bureau, Indianapolis, Ind.]

Tornadoes occurred Monday, April 17, 1922, in Indiana and other States of the Ohio and middle Mississippi Valleys in connection with a trough-shaped area of low pressure which extended from the upper Lake region southwestward to Texas and moved slowly eastward during the 24 hours following 7 a. m., Monday. The tornadoes appearing in Indiana during this period probably crossed from Illinois. The first one struck southwestern Parke County¹ about 2 a. m. and wrought damage estimated at \$10,000, but injured no one. About one-half hour later, the second one appeared a few miles southwest of Williamsport, Warren County, killed one person and damaged property to the extent of \$50,000. At 3 p. m., Brook, Newton County, was hit, and two persons were killed and one other was injured and property worth \$6,000 was destroyed.

At about 4 p. m. the third and principal tornado,² apparently after having traveled 35 miles in Illinois, entered Warren County, 5 or 6 miles northwest of Attica, and worked destruction on the country near Hedrick, Sloan, Williamsport, and Attica. Rotary winds, a funnel-shaped cloud, with the attendant roar, a narrow path of total destruction, and instances of buildings exploding

¹ Probably the Washington County, Ill., tornado.—Editor.² Probably the Odgen, Champaign, Ill., storm—see preceding article.—Editor.

from within, carrying the walls outward, were observed during the storm and were reported. During the comparatively short time of passage it killed 11 persons and injured 30 or 40 others and damaged property estimated in value at \$150,000 to \$200,000. The path of the storm extended nearly from west to east, with a slight northeasterly trend and varied in width from a few feet up to a half mile, although the path of greatest destruction averaged only 100 yards in width and varied as the tornado cloud rose and fell during its progress. The length of the path at this point could not be fixed definitely but from the data available it was estimated at 8 miles.

This storm appeared again at 6 p. m. in Madison County, about 125 miles east of the point of its first appearance in Indiana. The direction of progress, the sequence in time, and the characteristic of these storms in skipping stretches of country in their progress point to the conclusion that this was the same storm which appeared earlier, although such material evidence as was present in the incident described below was lacking in this instance. The path extended from Orestes, Madison County, to Wheeling, Delaware County, a distance of 25 miles to the northeast, and averaged about one-half mile in width. The storm was observed also at Alexandria and near Summitville, and after passing Wheeling it seemed to widen out and became rather a general wind storm. The diameter of the tornado cloud was estimated by observers at 100 yards, but probably was less than this near the ground. Three persons lost their lives, about 25 others were injured, and property was damaged to the extent of \$100,000 to \$150,000 in the progress of the storm across this section of the State.

The following item appeared in *Indiana Daily Times* of April 24, 1922, and the facts were afterwards verified by correspondence with the postmaster at Orestes, Ind. It is submitted as an interesting phenomenon in connection with the study of this storm. Mount Cory, Ohio, is 124 miles from Orestes, Ind., according to the mileage along the Lake Erie & Western Railroad, and lies in a somewhat northeasterly direction.

When the home of Mrs. Bessie Porter in Orestes was destroyed by a tornado, Monday night, April 17, a picture post card was picked up from the ruins and carried with the tornado. The post card has been returned to the postmaster at Orestes, coming in a letter from J. O. Kistle, of Mount Cory, Ohio. In the letter Mr. Kistle stated a tornado struck a short distance south of his home on the morning of April 18 and he found the card lying on the ground while on his way to work. The card, which showed a view of Hartford City, Ind., was torn at one corner, but otherwise was in good condition. Mrs. Porter said that it was one of several that she had in an album at her home.

Other storms, violent in character, also occurred at Corydon, Jasper, and near Stinesville on this date, but judging from all available reports were not true tornadoes.

IN OHIO.

By W. H. ALEXANDER, Meteorologist.

Apparently the first of these local storms to assume tornadic form and force occurred on the afternoon of the 10th and seemed to start at or near Riverside (formerly Harshmanville), $3\frac{1}{2}$ miles northeast of Dayton, and moved in a northeasterly course, touching the extreme northwest corner of Greene County, crossing Clark County, into and perhaps across Champaign County, finally dissipating either in Union or Delaware County. This storm seems to have been a real tornado, as quite a number of persons report seeing the "funnel-shaped cloud," and the destruction wrought indicates a storm of this kind.

Mr. W. J. Moxom, official in charge of the Weather Bureau office, Dayton, Ohio, makes this observation:

I observed a very peculiar cloud passing over Dayton just a few minutes before the time of destruction at Harshmanville. This cloud was

very black in parts and gray in others and was at an elevation of approximately 1,000 feet. It was moving very fast and rolling violently. I am inclined to believe this was the cloud that developed into a tornado immediately after passing over Dayton to the higher ground northeast of the city.

Mr. Moxom also furnished the following account of this tornado by an eyewitness, Mr. Charles E. Semler, 1204 U. B. Building, Dayton, Ohio.

I was driving in my machine from Fairfield to Dayton along the Dayton-Springfield pike on April 10, and about 4.45 p. m., just after leaving Fairfield, I noticed a very peculiar shaped cloud in the southwest. This cloud was approaching very rapidly and was very black. At very short intervals it would reach to the ground and when touching the ground had the regular funnel shape. I stopped my machine in order to avoid being in its path and it crossed the pike about one-half mile from where I was stopped. There was not much roar that I noticed, but it was whirling violently, and I noticed some few parts of debris in the upper outskirts of the cloud. I went over the scene of destruction the next morning. On the John Mays farm it destroyed a large barn and unroofed the large brick residence. On the Will Mays farm, about one-eighth mile to the northeast, it unroofed the barn and frame dwelling house. There was some damage on the Gross farm.

In the woods on the Miami Conservancy land south of the pike the storm cut a path about 150 feet wide through the timber, uprooting some trees and breaking other large trees off several feet from the ground.

Other and very reliable details concerning this tornado may be found in newspaper clippings, from which it appears that one person was killed by the collapsing of a barn, another by lightning, quite a number were more or less seriously injured, and property variously estimated from \$100,000 to \$200,000 destroyed.

Another tornado occurred during the evening (about 8 o'clock of the 17th) in the northwestern part of Auglaize County, doing its greatest damage apparently in the vicinity of Buckland. This storm seems to have originated in Noble Township, moved northeast, and dying out in the vicinity of Hume, in the southern edge of Allen County. While no human life was lost so far as known, a number of people were injured and very considerable property was destroyed.

A comparison of the daily weather maps of the 7th, 10th, and 17th reveals a very striking similarity in the pressure distribution that seems to have brought about these stormy days in Ohio. On each day there was a barometric trough extending from the Lake Region southwestward to Texas or the upper Rio Grande Valley; in two cases, the 7th and 17th, the major center was in the northern end of the trough and on the 11th in the southern end.

IN ALABAMA, MARCH, 1922 (DELAYED REPORTS).

[Abstracted from a report by P. H. SMYTH, Meteorologist.]

Two small tornadoes were observed in Cullman County, Ala., both of which traversed almost identical paths for a short distance. The first occurred on March 14 in the evening; it was lacking in violence and quickly dissipated. The second was a more fully developed storm; its path can be traced from Crane Hill, 15 miles southwest of Cullman, to that town, thence northeastward, crossing Morgan County and probably passing into Madison County. Three persons injured, no lives lost, property loss \$100,000.

A third tornado was observed at Salem, Lee County, about dark March 19. It moved thence eastward, increasing in violence, and, passing over the small village of Wacoche Valley, demolished a church, store, and three dwellings. At Goat Rock, east of Salem, a transmission tower was blown down and two persons were killed. The path of greatest destruction was about 200 yards wide in places; there was some hail, not much rain, and vivid lightning.

RAINFALL AND FLOOD AT FORT WORTH, TEXAS.

By D. S. LANDIS, Meteorologist.

[Weather Bureau, Fort Worth, Tex., May 25, 1922.]

During the night of April 24-25, 1922, Fort Worth, Tex., was visited by the severest electrical storm it ever experienced, accompanied by rainfall unprecedented in the history of the local United States Weather Bureau or in the memory of oldest inhabitants, which resulted in flood waters of the Trinity River reaching the highest stage of record.

The weather chart of the morning of the 24th showed the primary low-pressure area overlying the southwest, with Phoenix, Ariz., as the center of depression, reduced barometer reading 29.76 inches at time of observation on the 24th, and 29.70 at the morning observation date of the 25th. High pressure prevailed in the northern Rocky Mountain regions and also over the territory east of the Mississippi River, permitting the outflowing surface currents of each high-pressure area to flow into this primary low-pressure area over the southwest.

This relation of the two HIGHS and the primary LOW remained practically unchanged for fully 48 hours, and as long as these relations were maintained and the barometric pressure at Fort Worth continued to increase, heavy to torrential rains persisted at Fort Worth.

All day of April 24 the sky was wholly overcast with heavy alto-stratus clouds having quite rapid movement from southerly directions, primarily from the south, until about sundown, at which time cloud movement seemed suspended except in lowering, sagging, and bellying, vast smoky-looking detachments bagging downward at various points in the northwest, making one think of huge conical stalactites suspended from a darker-colored ceiling of cloud surface. These detachments would slowly dissolve in lowering, disappearing almost suddenly as if swallowed up by some stratum of differing temperature.

No marked commotion was detected in the clouds, yet a sharp barometric depression resulted at 4:30 p. m., attended by a thunderstorm, accompanied by wind from the southeast at 4:39 p. m., attaining 46 miles an hour for a period of five minutes. With the passing of the thunderstorm the wind abated rapidly, barometric pressure increased, rising almost to the level that obtained prior to the beginning of the thunderstorm, reduced pressure being close to 29.92 inches. Wind velocities now varied from light air to light breeze, though abruptly shifting from the southeast to the northwest, back through the west, again to the southwest, and finally to the south, continuing in the south from 9 p. m. through midnight, velocity never reaching above 8 miles an hour until midnight, after which hour the wind blew from the east at moderate breeze velocity until 4 a. m. of the 25th.

By 9 p. m. of the 24th the wind had died down to 4 miles an hour from the south. The stillness was oppressive and darkness so dense as to be inexpressible. At 9 p. m. lightning darted hither and thither in the northwest and northeast, and continued until 9:39 p. m., then there burst forth deafening peals and crashes of thunder, accompanied by sheet lightning that made the heavens seem on fire, while forked streamers of electrical discharges radiated from countless points. The crackle of the electricity on near-by wires was continuous and suggestive of a highly surcharged condition of the

atmosphere. The close-range thunder seemed to cause the earth to tremble and dwellings to rock, the rapid crashes and reverberations resulting in a continuous roar, scarcely abating from 9:39 p. m. of the 24th until 1 a. m. of the 25th.

Rain began falling at 9:06 p. m. of the 24th, large drops at first, gradually thickening, reaching an excessive rate of fall by 11:39 p. m., and continuing until 1 a. m. the 25th, as above stated.

TABLE 1.—Accumulated depths during excessive rate, for consecutive periods of time.

5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
0.06	0.14	0.31	0.54	0.70	0.75	0.89	1.28	1.63	1.89	2.43	3.07	3.62	4.07

From 10:19 p. m. of the 24th to 7 a. m. of the 25th there fell 7.50 inches of rain. Between 12 midnight and 1 a. m. there was a record of 2.50 inches for the hour; 1.02 inches fell in 15 minutes; 1.74 inches in 30 minutes; the maximum fall in 2 hours was 4.06 inches. The 24-hour precipitation amounted to 8.81 inches, actually occurring within 14 hours and 22 minutes.

The resulting flood.—Fort Worth, Tex., is located a short distance below the juncture of two small streams, the Clear Fork and the West Fork, the union of which forms the Trinity River. The drainage area above the city embraces 2,300 square miles. Reports from two points in the upper reaches of the drainage area warrant the belief that the torrential rains covered the whole drainage area, hence the unprecedented flood of April, 24-25, 1922.

It is desired to digress here to give data of former heavy rainfall and resulting floods. On September 20-21, 1900, local rainfall measured 7.44 inches within 24-hour period, resulting in flood waters reaching an estimated depth of 38 feet, but the rise was so gradual as to result in very little destruction other than still water effects.

On May 24-25, 1908, local rainfall measured 6.99 inches, occurring within 15 hours 13 minutes. River stage estimated from ripple marks on bridge showed 39 feet. But little loss of property and life resulted, owing to the slow rising of the waters, and the fact that there was daylight, too, prevented anyone being trapped by the flood.

The above-mentioned floods were of little moment to property or life, but the flood of April 24-25, 1922, had other factors not found in former floods. Levee protection, which was depended upon, was the outstanding element that militated against such protection. The river proper at the Government river-gage is 98 feet wide in channel. Back 100 feet from the channel a 10-foot-high levee was thrown up and grassed over. This levee gave a channel practically 298 feet wide, and 30 feet to river-bed level, supposedly allowing sufficient channel for any flood waters likely to occur. The test came the morning of the 25th. At 7 a. m. the river-gage showed 33.5 feet, being 3.5 feet above flood stage and

running over the levee. No one knows how long the water had been over the levee, for the rainstorm had been so intense and the electrical storm so terrific that it appears that no one had ventured out to note conditions.

The residential lowland district was under water before any one knew it, house pets giving first alarm by cries and scrambling for places of safety. People stepping out of bed found water ankle deep, and more, already in their homes, and the flood soon became waist deep. Ceilings were opened and refuge taken in lofts, and daylight found many people marooned on housetops awaiting rescue.

By 7:30 a. m. a crevasse was made in the levee some distance above the residential district, and the flood filled in rapidly, water running into residence windows by 10 a. m., and reaching the eaves of many homes by

2 p. m., when the flood crest stood highest of record at this station, 39.1 feet.

The lowland residential district embraces about 4 square miles, and about 1,500 inhabitants were subjected to overflow waters. After the levee broke many head of live stock drowned in their stalls, at hitching posts, in wire entanglements, in hobbles and lariated, while many head of other animals were washed away.

While there are but 11 known dead, many are missing and can not be accounted for by any reasoning other than that they have been drowned and buried in drift and river débris. Losses can only be estimated. The reckoning embraces losses within the city limits, probably reaching half a million dollars affecting live stock, municipal properties, and homes and home furnishings, while the item of clean-up expenses will run into thousands of dollars.

RAINFALL OF COLOMBIA, SOUTH AMERICA.

ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, D. C., May 28, 1922.]

In this REVIEW 50:146 announcement was made of the proposed establishment of a meteorological service in the Republic of Colombia. In view of the fact that exceedingly few series of meteorological observations are available for that country, it has seemed advisable at this time to make an inventory of such as are available and publish it in the interest of all concerned. As the title of this note suggests, rainfall only will be considered. Temperature observations are likewise very few in number, but the geographic position of Colombia, together with the known rate of decrease in temperature with altitude, make the deficiency in observational material less serious than in the case of precipitation.

Precipitation measurements varying in length from 1 to 10 years are available for but 10 stations, and 6 of these are along the Pacific Railroad from Buenaventura to Cali on the Cauca River, a distance of 108 miles. For these latter only the annual totals are available.

The rainfall of Colombia is almost wholly of the convective type and is clearly associated with the declination of the sun as the latter successively crosses parallels of latitude on its northward progress at the vernal equinox and on its return journey southward at the autumnal equinox. The rainy seasons, of which there are two in the zone between the Equator and say 8° north or south latitude, separated by relatively dry seasons, are coincident with the time of zenith sun at midday. The first wet season occurs in the months of April, May, and June and the second in September, October, and November. In latitudes more distant from the Equator the two wet and the two relatively dry seasons merge into a well-defined wet and dry season, respectively, of varying length and without sharp lines of demarkation between the two. On the Pacific coast of Colombia, however, rain falls almost daily and there is no dry season; in other localities there is considerable rain in the so-called dry season.

The annual totals in inches are presented for the 10 stations in Table 1.

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TABLE 1.—Annual rainfall in Colombia, South America (inches and hundredths).

Years.	Buena- ventura. ¹	San Jose. ²	Cal- das. ³	Pal- mar. ⁴	Lo- mitas. ⁵	Yum- bo. ⁶	La Man- uleta (Cauca Valley). ⁷	Medel- lin. ⁸	Bo- gota. ⁹	Pato mines on Rio Neche.
Elevation (feet).	Sea- level.	600	2,500	(?)	.....	(?)	3,500	5,216 ⁷	8,612	.....
1849.....										
1881.....										74.40
1882.....										54.25
1883.....										35.97
1900.....							39.97			39.35
1901.....							45.21			
1902.....							33.80			
1903.....							56.38			
1904.....							37.74			
1905.....							33.79			
1906.....							39.96			
1907.....							47.80			
1908.....							54.94			
1909.....							55.13			
1910.....	323.96	270.00	57.08	34.06			48.50			
1911.....	248.66	277.37	46.66	25.41	33.34					
1912.....	265.10	400.88	54.56							
1913.....	234.90	296.10	50.11			37.73				143.6
1914.....	262.86		31.09							
1900-1910 ¹⁰								62.83		
1875-1879 ¹¹							44.66			

¹ 11 months.

² 5-year mean.

³ 11-year mean.

⁴ *Bul. Amer. Mus. Nat. Hist.* 36: 79-83, The distribution of bird life in Colombia, Frank M. Chapman.

⁵ *Met. Zeit.* 3: 419.

⁶ *Signal Service International Bulletin*, 1880-1884.

Remarks on Table 1.—Buenaventura is the sea-level terminus of the Pacific Railroad of Colombia; San Jose is distant therefrom 23 miles and in the region of heavy tropical rains. The station Caldas, 51 miles from the coast, is in a relatively arid pocket or basin shut off from the prevailing westerly winds by a mountain ridge which apparently robs the winds of their moisture. The stations Palmar and Lomitas are apparently on the Pacific slope; the details are missing, however, and the reason for the relatively small rainfall is not known.

The record for La Manuelita was made on the sugar estate of Mr. Charles J. Eder about 5 miles northwest of Palmyra.

TABLE 2.—Mean monthly precipitation (inches).

Stations.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Bogota.....	3.04	3.62	3.97	7.88	6.79	3.99	2.71	2.71	2.22	8.01	7.75	4.44	57.13
La Manuelita..	3.19	3.10	4.16	6.09	5.37	2.92	1.50	1.49	2.98	5.81	4.78	3.20	44.59
Medellin.....	2.16	2.52	5.27	6.93	7.76	6.61	4.13	5.12	6.42	7.36	5.87	2.68	62.83

Seasonal distribution.—Table 2 contains the monthly averages for the stations, Bogota, on the high table-land; La Manuelita, in the upper Cauca Valley; and Medellin, the capital of the Department of Antioquia. The latter is the largest of the inhabited departments of the Republic; its capital is situated at the junction of at least four mountain ranges at an elevation of about 5,000 feet. It is an example of those cases where the pause in the wet season is not well marked, there being fairly heavy rains in July and August. La Manuelita at a less elevation and slightly nearer to the Equator has two wet and two dry seasons, although not sharply defined. The rains of Bogota show a slight diminution in July, August, and September and in a less degree in January and February.

Finally, Table 3 gives the monthly amounts for Bogota and Pato mines in Antioquia. The record of the latter is for a single year only, but it illustrates the variable nature of wet and dry seasons. The dry season in the particular year here given was confined to the two months February and March.

TABLE 3.—Monthly precipitation (inches) for Bogota and Pato mines.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
BOGOTA.													
1848 ¹					7.80	3.07	3.19	3.23	4.76	7.80	15.75	9.61	.....
1849 ¹	5.47	3.35	3.90	12.72	8.50	4.84	4.06	6.02	1.97	10.39	7.79	5.39	74.40
1850 ¹	5.32	5.08	3.11	6.26	5.79	.....	.....	.....	.....	.....	.....	.....	.....
1880 ².....	.....	.....	10.12	9.61	7.28	2.24	1.97	2.40	2.09	5.67	3.98	2.87	.....
1881 ².....	.....	28	5.32	1.02	9.84	4.25	2.64	1.30	1.61	2.80	9.80	10.71	4.68
1882 ².....	.....	08	3.50	3.50	2.56	3.94	3.15	2.13	2.76	.94	5.83	5.59	1.93
1883 ²	4.13	2.05	1.89	8.19	4.53	.....	2.80	1.89	.79	8.11	2.80	2.17	39.35
1884 ²	2.95	2.44	4.25	5.94	5.47	8.03	3.54	1.06	2.20	8.46	.....	.....	.....
Means.....	3.04	3.62	3.97	7.88	6.79	3.99	2.71	2.71	2.22	8.01	7.75	4.44	57.13
PATO MINES, ON RIO NECHE, ANTIOQUIA.													
1913.....								17.4	20.3	15.7	18.6	7.8	.....
1914.....	8.7	1.8	0.6	8.8	18.8	14.4	10.7	.....	.....	.....	.....	.....	143.6

¹ *Annuaire de la Société Meteorologique de France* 1: 269-272. 1853.

² *International Bulletin Sig. Ser.* 1880-1884.

In the *Industrial and Commercial Handbook of Colombia*¹ Trade Commissioner P. L. Bell has collected considerable information of a nonstatistical character on

¹ Department of Commerce, *Special Agents Series No. 206*, Colombia.

the rainfall of that country which briefly summarized is as follows:

Caribbean coast country.—A tropical low-lying coast region, dry and semiarid from the peninsula of Goajira as far as Santa Marta, with the rainfall and vegetation increasing from Barranquilla and Cartagena until the region of the Atrato River is reached, where extreme tropical conditions prevail and the rainfall is as heavy as anywhere in the Tropics, being equal to that of Panama. * * *

The Santa Marta region receives slightly more moisture than Rio Hacha (to the east in the Goajiro country), but not enough to mature crops, irrigation having to be resorted to in the banana district south of Santa Marta harbor. The average precipitation in this latter region does not exceed 14 inches. The Caribbean coast in the region of Barranquilla and Cartagena receives more rainfall than Santa Marta, but still not sufficient to mature crops very well, there being frequent years of extreme drought lasting from October to May. The annual average precipitation is about 26 inches.

Interior.—Farther south along the ranges of the central Andes, in the region of Medellin, the climate changes. There are two wet and two dry seasons, the former occurring during April, May, and June and during November and December. Still farther south along this range, as at Manizales, elevation 7,000 feet, the seasons and the amount of rainfall, the latter averaging about 60 inches per annum, are the same but the temperature is lower and may be called ideal. * * *

In the Cauca Valley conditions are about the same as for the second zone, with two wet and two dry seasons, the climate being called semitropical and the temperature averaging 76°.

Pacific coast.—Along the Pacific coast and the western slope of the Cordillera and the small northern range of coast hills, rains are incessant and very heavy, equaling the fall in the Atrato region and that of Panama. At the Pacific port of Buenaventura it rains every day, and the annual precipitation is more than 160 inches. This heavy rainfall on the coast diminishes farther south and in the neighborhood of Tumaco is reduced to the normal amount of 60 inches per annum on the average.

METEOROLOGICAL NOTES ON CANTON, CHINA.

By GEORGE D. HUBBARD.

[Oberlin College, Oberlin, Ohio, Apr. 5, 1922.]

The Freeman Meteorological Observatory, founded in 1918, is located on the campus of the Canton Christian College, 23° 06' N., 113° 19' E., about 1,200 feet from the Canton River. This river is subject to tides at Canton, although about 80 miles from the sea. The shelter is 30 feet above mean river level and consists of a 30-foot-square mat shed which has open sides to a height of 3 feet from the ground and a sloping double roof of palm leaves supported on a bamboo frame. In this shelter are the air thermograph, soil thermograph, barograph, and hygrograph, each making continuous records, and the thermometers and psychrometer for current measurements of air temperature and humidity. Outside the shelter are an evaporation pan, a still well, and an anemometer for measurement of evaporation, a standard rain-gauge, and a thermometer suspended 18 inches underground in a bamboo tube.

On the roof of one of the college buildings are a wind vane and an anemometer and electric sunshine recorder, which are connected to a register in the physics laboratory. There is also provided a tide-well with a continuous-record register. Summaries of the daily observations of all the instruments are published monthly in a four-page leaflet which can be had by any service offering a reasonable exchange.

The author has obtained the records for 1919 and 1920 and herewith presents a summary of monthly totals and averages of six or eight of the elements, which is about half of the items covered by the observatory.

	Monthly precipitation in centimeters.	Number of days without rain.	Average daily evapora- tion in centimeters.	Amount of wind in kilo- meters. Daily aver- age.	Extreme wind velocity in meters per second.	Average humidities by months.	Maximum temperature in each month. De- grees C.	Minimum temperature in each month. De- grees C.
1919.								
January.....	1.46	22	0.22	474	19.7	82	27.9	3.8
February.....	10.22	9	.18	506	21.5	83	23.2	1.4
March.....	5.22	17	.23	449	16.1	88	29.0	11.0
April.....	22.16	12	.36	484	32.2	86	32.1	12.1
May.....	10.58	17	.45	423	22.3	82	32.2	16.3
June.....	29.70	8	.55	397	29.5	86	33.2	23.0
July.....	21.01	19	.63	408	24.1	84	34.3	23.0
August.....	23.20	18	.58	484	29.5	79	35.4	23.4
September.....	3.84	22	.50	364	24.1	76	32.8	20.5
October.....	7.54	23	.47	401	18.8	81	31.8	12.4
November.....	7.12	23	.40	439	15.7	71	29.4	5.4
December.....	4.11	27	.33	529	25.0	71	22.4	4.9
Totals and averages.	146.16	217	.41	451	.....	80.7	35.4	1.4
1920.								
January.....	0	31	.30	484	24.1	65.0	23.5	2.1
February.....	26.50	12	.16	555	21.5	86.0	26.3	6.3
March.....	10.28	13	.22	417	21.5	86.0	28.4	8.0
April.....	34.96	10	.30	384	27.3	86.0	28.7	14.4
May.....	37.76	14	.40	414	32.2	86.0	32.0	20.0
June.....	24.80	12	.53	385	26.8	85.3	33.2	21.6
July.....	50.32	11	.60	525	24.6	83.5	35.7	24.2
August.....	54.65	11	.47	364	24.6	91.0	33.5	23.1
September.....	12.66	14	.51	346	24.1	80.0	33.7	22.5
October.....	3.48	23	.35	389	17.9	70.0	33.0	16.3
November.....	11.66	20	.36	392	18.8	76.0	29.6	12.4
December.....	5.73	20	.21	462	23.2	79.0	29.5	7.6
Totals and averages.	272.80	191	.37	426	.....	81.1	.....	.....

For many of the items two years' observations do not seem to be sufficient upon which to base a description of the climate, but many interesting points may be noted. The rainfall for 1920 was almost twice as great as for 1919, and this seems to be due to a larger precipitation in almost every month, to longer rains, and more rain per day. We have no way to ascertain which is nearer the average for Canton. January of the second year had absolutely no rainfall, and of the first year had 1.46 cm., distributed over nine days. There seems to be a definite seasonal distribution of the rainfall. October, November, December, and January had a total of 95 days of no rain in 1919 and of 94 days in 1920, while the four months April, May, June, July had 56 and 47 days with no rain in their respective years.

While many days had only a small fraction of a centimeter of rainfall, several days had a very heavy fall. In 1919, 11 days had over 2.5 cm. and 1920 had 34 similarly rainy days. These days are scattered all through the year from February to November in each case. December and January are the dry months, also the months with no heavy rain. The heaviest one-day precipitation fell on July 19 in the second year, when 26 cm., or over 10 inches, was recorded. No other day in the whole period attained quite half this record. While the more rainy months and all the heavier rains come during the season of the southeast monsoon, yet the rainiest day came when the wind was from the west. Of the eight heaviest rainy days, four had east winds, one north wind, two south winds. These heavy rainy days are frequently preceded and followed, within a day or two, by wind from the same direction with no rainfall.

Although there is a rather distinct rainy and dry season, the sunshine recorder, which operated about 16 months out of the two years, never showed a full day of sunshine. Eleven hours was occasionally exceeded, but usually only a few days in the month had sunshine more than six hours. The summer and early fall seem to be

the sunniest times. One September had 22 days in which the sun shone over six hours. The Octobers had 14 and 16 such days, the Novembers had 8 and 7 such days, and the Decembers, 13 and none. In 1920, February had 24 days with no sunshine, March 20 days and April 10, while July had 23 days with over six hours sunshine and still had over 50 cm. of rainfall. Mornings and evenings banks of stratus clouds are common, and through all the warmer weather the cumulus cloud is very common.

The humidity figures given in the table indicate the subtropical monsoon conditions, and the average relative humidities for the two years are only 0.4 per cent apart, in spite of the fact the more humid year had twice as much rainfall. Only twice in the two years did the humidity for a day fall below 50 per cent. Those were days in December and January. This humidity is determined by averaging three readings, taken at 7, 1, and 6 o'clock. Ten months out of the 24 had at least one day with an average humidity between 50 per cent and 60 per cent, and these are scattered well through the years—January, 2; May, 1; September, 1; October, 2; November, 2; December, 2. Several days carried an average humidity for the day of over 96 per cent. The mean daily evaporations for the two years are 0.41 cm. and 0.37 cm., respectively, although the daily average for February fell to 0.18 and 0.16 cm., respectively, and in July it rose to 0.63 and 0.60 cm., respectively. There is here a reflection of the temperature, but not of the humidity or monsoon wind effect.

The wind direction is apparently the normal monsoon. In October, November, December, January, and February it is very constantly from the north, while in April, May, June, July, and August it is pretty steadily between south and east. While the direction is fairly constant, the velocity varies greatly. The maximum velocities observed run from 15 or 16 meters per second in October and November to 32.2 meters per second in April and May. The instruments have recorded the amount of wind in kilometers per day. Eleven days in the two years have to their credit over 1,000 km. of wind, and one of these exceeded 1,400 km. These days of heavy wind fell two in January, one in February, two in July, three in August, and three in December. The lowest amount of wind recorded was 117 km. on June 28, 1920. On November 9 of the same year none was recorded at all, and the maximum velocity that day was 2.2 m. per second. Such a day in November would be very comfortable, but the one in June must have been as sticky as a glue pot.

The maximum, minimum, and range of temperatures as shown in the above tables are about what would be expected in a subtropical climate. It is earnestly hoped that this excellent piece of work carried on by the college will be continued for many years to come and that the results will have a wide circulation for the observatory is very completely equipped and the observers are careful and competent.

CLIMATIC FEATURES OF SANTOS, BRAZIL.

[Abstracted from report furnished by U. S. Vice Consul Herndon W. Goforth, Santos, Brazil, Jan. 20, 1922.]

Inasmuch as Santos is the greatest coffee port in the world, Brazil's leading export center, and a popular place of residence (population over 100,000), the following notes on the climatic features may be of some interest:

Santos is on the island of São Vicente, immediately off the coast of Brazil, 200 miles southwest of Rio de Janeiro. The chief part of the city is but 7 feet above mean sea level.

"The entrance to São Vicente for vessels from the open sea is through a strait, perhaps 5 miles in width, formed by the headlands, several hundred feet high, of two adjacent islands which extend several miles farther seaward than does São Vicente. Behind the city on the north, and also on the east and west sides, at a distance of less than 10 miles, is the Serra, a chain of mountains about 3,000 feet in altitude. * * * Santos is therefore entirely surrounded by mountains except for the 5-mile strait to the south."

"The climate [weather] of Santos is largely a matter of how the wind blows. In general, if the wind is overland from the northwest, the temperature steadily rises until it occasionally reaches or even exceeds 100° F. This 'norwester' sometimes continues for several days, but more often a single day or a few hours is sufficient to raise the temperature in the basin, or low-lying portion of the island, to a height sufficient to cause the cool air from the sea to rush in through the strait with hurricane force, drive the heated air upward and over the mountains, lower the temperature in the city, and bring a deluge of rain in its wake. It is not a rare occurrence to have several storms of this kind within 24 hours, although during the cool season they are not so frequent and two or three weeks of rainless weather may intervene."

The subjoined tables of temperature and precipitation need little explanation. It will be noted that the hot season extends from December to February, inclusive, and the cold season from June to August, inclusive. The mean temperature of the coldest month (July) is only about 15° F. lower than the mean of the warmest month (January or February). In general, temperature conditions are not very sharply defined by months. The extremes of temperature so far recorded are 38° and 105° F., respectively.

Rainfall seems to be even more variable, the annual amounts ranging between 50 and 110 inches, with a mean of about 77 inches.

The author further remarks: "Since the climate of Santos is extremely damp, there being occasional periods of as long as 10 days without sunshine, shoes and other articles of clothing mold badly unless frequently aired and sunned. The prevention of rust on all articles of metal is extremely difficult. Nickeled ware usually does not withstand the humidity, as the nickel almost always peels. Complaint on the part of local merchants is frequently heard to the effect that the tin containers used for packing certain goods imported from the United States, such as fruits and fish, become so rusty as to greatly injure the sale of the article. American chocolates are not carried in stock at Santos, since it has been found that they do not withstand the climate long enough to permit of being sold. Special packing, and in

some cases a difference in the preparation of the article itself, is therefore a requisite to success in establishing the sale of certain kinds of American goods."

TABLE 1.—Mean annual temperature and rainfall at Santos, Brazil, for the 10-year period 1911–1920.

Year.	Temperature.	Rainfall.	Year.	Temperature.	Rainfall.
	° F.	Inches.		° F.	Inches.
1911.....	69.4	109.8	1917.....	66.0	88.4
1912.....	69.6	85.9	1918.....	69.3	75.6
1913.....	70.7	80.0	1919.....	69.6	78.6
1914.....	70.5	51.3	1920.....	69.6	84.0
1915.....	70.3	65.6			
1916.....	68.9	55.7	Mean.....	69.4	77.5

TABLE 2.—Average monthly temperature and rainfall at Santos, Brazil, during 1916 and 1918.

	Temperature.		Rainfall.	
	1916	1918	1916	1918
	° F.	° F.	Inches.	Inches.
Summer:				
December.....	76.5	76.3	9.2	6.0
January.....	76.3	76.8	4.1	5.8
February.....	75.9	77.2	5.5	4.8
Mean.....	76.2	76.8	6.3	5.5
Fall:				
March.....	75.0	77.0	11.9	9.9
April.....	72.1	74.7	7.8	6.6
May.....	69.4	70.7	5.7	11.6
Mean.....	72.2	74.1	8.5	9.4
Winter:				
June.....	68.9	65.7	3.7	5.0
July.....	65.3	61.7	1.5	5.4
August.....	63.9	62.6	1.7	2.9
Mean.....	66.0	63.3	2.3	4.4
Spring:				
September.....	69.1	66.4	2.4	3.0
October.....	68.9	67.7	9.9	6.5
November.....	74.3	73.4	4.7	9.6
Mean.....	70.8	69.2	5.7	6.4
Year.....	71.3	70.9	68.1	77.1

TABLE 3.—Monthly rainfall at Santos, Brazil, July 1, 1920–June 30, 1921.

Month.	Inches.	Month.	Inches.
1920.		1921.	
July.....	3.45	January.....	10.61
August.....	3.23	February.....	22.92
September.....	6.52	March.....	7.27
October.....	4.88	April.....	8.75
November.....	8.55	May.....	1.19
December.....	4.50	June.....	2.86

Total for 12 months=84.73 inches. The annual average is 96.34 inches.

THE PROBLEM OF AGRICULTURAL ECOLOGY.

By G. AZZI.

(International Institute of Agriculture, Rome, Italy, Apr. 5, 1922.)

"We must come universally to the practice of producing seed adapted not only to the region, but to the individual locality."—C. S. Brand, United States Department of Agriculture.

Too little attention has been paid up to the present to the study of environment in agriculture. As yield is the result of a compromise between specific productivity and resistance to the most adverse phenomena, will it be possible to come to any conclusion relative to data for sowing, choice of variety, etc., when one of the terms of the compromise is absolutely or almost completely disregarded? It will be impossible, just as it is impossible for a tailor to make a suit for a man whom he has never seen and whose measure he has never taken.

By agricultural ecology we mean the study of the action of the different meteorological factors (in the atmosphere and soil) and the discovery of the extent to which it expresses itself with relation to the plant as regards the development and the yield. A more exact representation of environment will be of great use to the agriculturist and help him in all his endeavors leading to a better adaptation of culture to climate and soil. Researches conducted and data worked out by the method proposed aim at establishing for each plant cultivated (in the different points of its area of distribution) the genetic factors which rule its behavior in relation to environmental conditions and the exterior agents or group of agents which display the greatest influence on yield revealing the characters of susceptibility or resistance determined by the genetic factors.

Observations with reference to the relations between environmental factors and plant growth should be taken during the critical periods after determination of the optimum date for sowing. Frequency and intensity of adverse phenomena in connection with the critical periods will determine the degree of resistance that is necessary to overcome unfavorable conditions and produce a good harvest. Such determinations are not only useful, but absolutely necessary, to carry out plant breeding on a rational basis.

Collection of data.—To obtain meteorological figures and biological data for comparison, observations on meteorological factors and biological researches will be conducted on parallel lines in the same place.

Elaboration of data.—Leading to the determination of (1) critical periods; (2) frequency and intensity of the different meteorological phenomena; (3) phenological means.

Points 1-3 enable one exact biometeorological balance to be established. ●

Application of data (worked out as above).—Leading to the following results: (1) Choice of the variety most suitable to the given conditions; (2) best dates (5) for sowing; (3) most suitable cultural operations to escape unfavorable climatic conditions and best times for carrying them out; (4) a practical knowledge of environment for the plant-breeder to enable him to obtain the type (3) most likely to succeed under actual meteorological conditions.

The fact that the negative action of the meteorological factors has a decided influence yearly on the decrease in crop yield has for a very long time past attracted the attention of students and practical workers. In the year 286 B. C. Theophrastus asserted that *annus fructificat non tellus*, and was followed by Columella, Vergil, Varro, and a hundred others during the Greek-Roman period, the middle age, and up to recent times. On the

other hand, there is no agricultural country where the nature phraseology does not include proverbial sayings with special reference to the relationship between the critical periods of plant growth and weather.

At the present time observations are being made in connection with agricultural meteorological work almost everywhere. Before the war and revolution there was in Russia an excellent agricultural meteorological service, organized by Prof. P. I. Brounov, the founder of agricultural meteorology, and periodical publications on the subject were issued.

Many countries publish periodical information on weather and crops, and a considerable quantity of information has been accumulated, but without system or coordination. It is not really sufficient to make parallel observations on the development of a plant and meteorological factors unless some method is followed which will allow the utilization of the data thus accumulated in connection with the improvement of agriculture and the practical solution of the problems closely connected with agricultural meteorology.

Following up the works of preceding authors (Brounov, Warren, Smith, Gauer) and utilizing the present writer's own theory, I have combined all the elements and data into a new system of research.

For this purpose the following points, must be established: (1) The critical period; (2) phenoscopic averages; (3) the percentages of probability of the various meteorological phenomena for each 10-day period during the season of growth; (4) decrease of the yield caused by various unfavorable conditions (this decrease measures the intensity of action of the different unfavorable factors).

GENERAL RULES TO BE OBSERVED WHEN MAKING BIOMETEOROLOGICAL OBSERVATIONS.

Critical period.—This, for instance, as regards rain, is the term applied to the short interval of vegetative growth during which the plant absolutely requires a certain minimum of atmospheric precipitation.

If during the critical period the total rainfall is less than the minimum needed for the normal development of the plant, the crop will be small, even if there is an abundance of rain throughout the rest of the vegetative period. In the same way, should the requirements of the plant be satisfied during the critical period, the crop will be large, even if the rainfall is relatively scanty and badly distributed throughout the remainder of the vegetative period.

One of the critical periods of cereals falls within the 20 days before heading, and if at this time the rain is not sufficient to keep the soil moisture above a certain limit the grain crop will be seriously reduced.

This is, in fact, the moment when the plant is most active, and produces the vast amounts of plastic substances necessary for the formation and growth of the caryopses; during this process it consumes a large quantity of water. Between the heading stage and ripening there is on an average an interval of 40 days, and during these 40 days all the growth processes are abridged, the later stages following one another rapidly—flowering, setting, and the development and ripening of the caryopses.

It is therefore indispensable, in order to insure a good wheat crop, that the rainfall should be abundant during one or both of the 10-day periods before heading, so as to supply the plant with the moisture necessary for the rapid and important growth operations.

What has been said regarding rainfall holds good in the case of all the other meteorological factors and phenomena.

A simple inspection of yield, figures, and meteorological values, reported for the different stages of growth, will occasionally reveal at once the existence of the "critical period." But as the different factors act contemporaneously and the problems of interaction become more complicated, experimental control in every case will be necessary to isolate the action of a single factor.

Following the lines laid down, experiments were carried out by the writer last year with four varieties of wheat cultivated in pots in conditions rendering it possible to vary artificially the degree of humidity during the 20-day period before heading.

Results confirm fully the existence of critical periods. With the increase of irrigation there was a corresponding increase in yield (weight of grain per ear in centigrams).

The statistical method and formulas have been proposed (and largely applied) for determination of the correlation between yield and meteorological values, but this method should not be overestimated. In a general way mathematical formulas can not be used to discover or determine the degree of correlation between meteorological values and yield.

Diminution of product caused by a given rainfall over the optimum is not the same as the diminution caused by equal rainfall under the optimum. As the deviations have not a corresponding relationship to the optimum (as well as to the mean), the application of formulas (of correlation and regression) based on the study of deviations may lead to erroneous conclusions.

In some countries agricultural meteorology has fallen partially, at any rate, into the hands of statisticians and mathematicians, very fine formulas, graphs, and equations have been worked out, while the application of correlation and regression coefficients became the *leit motif* in agrometeorological researches.

It is to be feared that this work, important as it may be from certain points of view, will not always lead to practical results.

Phenoscopic averages.—In every district it is necessary to find out the average date of each stage of growth. Thus, in the case of wheat, the average date of germination, heading, flowering, etc., must be determined.

The critical periods, as regards the various meteorological phenomena and factors, always coincide with some stage of growth (heading, flowering, etc.), the mean phenoscopic data thus enable us also to fix the date of the critical periods.

Example.—At station A, the average date of the heading of wheat is May 10. The critical period of the wheat from the point of view of rainfall (soil moisture) falls, however, between April 20 and May 10—that is to say, in the 20 days before the ears develop.

Percentage probability of the different meteorological phenomena.—In 1910, in the district of Bologna, no rain fell during the two periods of 10 days preceding the heading of the wheat, which took place that year on May 15, and the crop turned out far below the average, being only 12 quintals per hectare.

During the first half of April, however, there had been abundant rain. By sowing sooner, or using an earlier-

ripening variety, it would have been possible to alter the date of the heading phase to April 25–30, so as to make the critical period for moisture coincide with more favorable weather conditions.

In order to do this it would, however, be necessary to know in October what the weather is to be in the spring. The weather can only be forecast with certainty for 24 or, at most, 48 hours. *Thus crops can not be adapted to the weather.*

But if it is impossible to foresee in the autumn the atmospheric conditions that will prevail at Bologna and Sciacca (Sicily) during the second half of April, one thing is very certain—viz., that drought in the second half of April is a much more probable and frequent occurrence at Sciacca than at Bologna.

If, therefore, it is not possible to adapt crops to the weather of the year, they can be adapted to the average climatic conditions, which can be shown by the percentages of probability—probability of frost, drought, storms, fogs, etc.

Brounov has already suggested that a 10 days' period be called "dry" if the total atmospheric precipitation does not exceed 5 mm., but if this definition can perhaps be accepted by the climatologist it is of very relative value to the agriculturist.

The important point is not the sum total of the atmospheric precipitation, but the amount of water actually at the disposal of the plant which is represented, at least to some extent, by the soil moisture. The latter, however, even when the amount of rain is equal varies within very large limits according to thermic, agroeological, topographical conditions, and the like. Therefore, in speaking of drought, we must adopt the ecological criterion and refer "to the complex of values and environmental relations producing a deficiency of the water required by a given cultivated plant."

This is a question for the biologist and comes within the province of plant physiology.

When once the meteorological values resulting in "dryness" have been determined on the basis of a thorough knowledge of the local agroeological conditions, the probable occurrence, or the frequency of these values, can easily be established for periods of 10 days.

By calculating for a certain district and for a long series of years (at least 20), the number of times a particular 10 days' period has been "dry" and expressing the results thus obtained as percentages, the figures will give the probability of drought during that period of 10 days.

If we suppose that at station A, the second decade in July is dry 15 times in 20 years, we can say that the probability of drought during that period at A is 75 per cent.

What has been said regarding drought also applies to all other meteorological factors or phenomena.

The determination of the decrease in yield due to different unfavorable meteorological phenomena.—Example.—Drought and wheat at station A:

(a) Average grain crop in years when drought has not prevailed during the 20 days previous to heading.

(b) Average grain crop in years when drought has prevailed during the 20 days before heading.

(c) The difference between the two crops (a and b) gives us the mean decrease in yield due to the drought. It may be assumed that this difference amounts to 5 quintals.

The comparative examination of the phenoscopic factors (the average date of heading) and of the percent-

age of the probability of drought permit the determination of the frequency of drought during the critical period at station A.

Suppose that the probability of drought during the two decades (periods of 10 days) before heading is 20 per cent (drought occurring in one year out of five). With a loss of 5 quintals per hectare owing to want of rain (as assumed) and with a 20 per cent probability of drought (one year in five), the annual reduction in yield caused by want of rain would amount on an average to 1 quintal per hectare.

Biometeorological balance.—By adopting this method it would be possible to construct a mathematically correct balance for every cultivated plant, for the different parts of its area of distribution.

Example: In the district of X the drought caused an average decrease of 2 quintals of grain per hectare, the frosts were responsible for a loss of 0.10 quintals, and lodging for a decrease of 0.50 quintal. In X, drought was the meteorological factor most injurious to wheat.

In the district of Y, 3 quintals were lost owing to lodging, 1 quintal from frosts, and 0.50 quintal through drought. Therefore, in Y, lodging (produced by heavy showers accompanied by wind) is the most injurious factor.

In this way it is possible to obtain a sure guide as to the means to be adopted in each district in order to limit the damage caused by unfavorable weather conditions. What are these means?

The manner in which a knowledge of the critical periods, of the decrease in yield due to various meteorological factors, the phenoscopic averages, and the percentage of probability and frequency of the different meteorological phenomena would make it possible to increase the yield by the progressively better adaptation of crops to climatic conditions.

Once the chief cause of the low returns is determined, there are three ways of finding a remedy.

(1) By altering the time of the growth stage for which the critical period has been discovered in such a way as to make this period coincide with more favorable weather conditions.

Example: The average date at which the variety of wheat heads at station A is May 18, while, on the other hand, the probability of drought during the last 10 days of April and the first 10 days of May (critical period) is 70 and 75 per cent, respectively. This is the reason of the somewhat low yield. In the first and second 10 days of April, however, the probability of drought falls to 10 and 15 per cent, respectively. Therefore by sowing or using an earlier ripening type of wheat, which would head between April 20 and 25, it would be possible to escape, at all events to some extent, the injurious effects of the want of rain.

(2) By artificially altering the meteorological conditions during the critical period—for instance, by irrigating in districts subject to drought. In such a case the knowledge of the critical period would enable much water and labor to be saved, as the operation could be confined to the time of actual and greatest need.

(3) Plant breeding to obtain resistant varieties to the most adverse meteorological conditions. This is of the most effective means of checking atmospheric influence. In this connection it is necessary to study the matter more in detail because of the great disappointments met with by some breeders in trying to export varieties to countries far from the original region and with different climates.

Most of the cultivated wheat varieties are from the genetic point of view more or less mixed types (populations) differing physiologically and morphologically in their fixed characters. The choice of these forms by pure-line breeding must be the first endeavor of the breeder with a view to obtaining later further improved types by hybridization and selection. On the other hand, good results can be obtained and breeds of consistent stability assured by the simple pure-lines selection.

As a result of this first trial some pure lines will be obtained, each one derived from a single parent plant and in all probability with very constant characters.

Among these, lines with high resistance to the most adverse meteorological condition and most adapted to particular conditions of a given locality should be chosen and the best date of sowing determined. Once this work is achieved no further improvement is possible unless mutations occur, which, however, is very seldom the case.

For further improvement it will be necessary to fall back on hybridization.

In the A station, exposed to drought, suppose a pure-line selection is obtained distinguished by its high degree of resistance. But as generally increased hardness (rusticity) is followed by lowering of specific yielding capacity, the new drought-resistant line will give a sure and constant yield (also in an unfavorable season), but somewhat low. In this case to get a higher yield it is necessary as already stated to proceed to hybridization.

Owing to the individuality and independence of characters (low and high yielding capacity, high or low degree of resistance to drought, etc.), as shown by phenomena of division and recombination of characters, it is possible to combine by crossing in one type two characters from two different parents (types).

In the case under consideration the local variety very resistant but low yielding will be crossed with another variety nonresistant to drought but showing a good yield.

Before crossing, the exotic variety should be acclimatized and undergo pure-line selection so as to control purity and become familiar with the specific characters. After hybridization the subsequent work of choice and isolation of forms should be carried on carefully and continuously with the idea of choosing between the numerous forms the form which combine the two characters "high yielding capacity" and "resistance" in the most favorable proportion with elimination of negative characters.

In Sweden, where low temperature is the most dangerous meteorological factor, excellent wheat varieties were produced very resistant to cold and giving a good yield by crossing the local resistant variety with the English Square-head, a good yielder. The work of hybridization and selection conducted by scientific methods for over 30 years has given the variety "Pansar," which yields 67 per cent more grain than the indigenous wheat. Pansar was obtained by crossing *Granadier* (a pure line, acclimatized from Square-head) with *Kotte* (a pure line from the indigenous Swedish wheat).

The use of the method suggested and described would lead to the following results:

(1) It would show which among the many varieties of a cultivated species, such as wheat, is the most suitable for a given district. The tendency to use and introduce over too-wide areas and in surroundings somewhat different from their place of origin the new products obtained by selection, or crossing combined with selection, has already led to many serious disappointments.

(2) It would show the best date for sowing with the view of making the critical periods coincide with the most favorable weather conditions without leaving out of account the length of the solar day, which exercises so great an effect upon the life of the cultivated plant.

(3) It would demonstrate the most suitable cultural operations and the best time to carry them out with the object of controlling the negative action of unfavorable meteorological factors or phenomena.

(4) It would guide the plant breeder in his efforts to unite in a single individual and in the best proportions for obtaining the maximum yield the character of "specific productivity" and of "resistance to the most injurious meteorological phenomena."

In the results obtained by the work of environmental analysis and of ecological synthesis, which has been extended to all parts of the area of present and possible cultivation, we should have the data necessary for the construction of the common basis, the fundamental plan of collaboration, on which should be founded the labors of the plant breeders of every country. From these data they will learn the requirements of the different climatic zones of wheat (and of other species of plants), and will be able to correlate their labors in a single well-devised effort to attain clearly defined aims.

The amount of risk from unfavorable weather conditions depends naturally on the intensity and frequency of such phenomena and on the possibility of adapting crops to climate in the way we have described. The atmospheric surroundings of a region then lose something of their instability and acquire a fixed character almost like the soil and the topographical conditions. It is possible and necessary to take them into account in judging a farm.

Paragraphs 1-4 describe the long and careful work of choosing suitable crops and adapting them to the climate. This work can not fail to have definite results, even if they are only partial, given the large scale on which it is applied and the high figures involved. The gist of the whole matter is, that the risk of loss (owing to unfavorable weather conditions) is reduced, and larger returns obtained without extra expense, which means a real increase in the value of the capital.

The problems of agricultural meteorology may, however, be subdivided into two main categories:

(1) *Weather forecasts*, which are in the province of the meteorologist, although they may be useful to the agriculturist in adapting his crops to the weather (defense against frost, etc.).

(2) *Agricultural climatology* (in a wider sense Agricultural Ecology), which aims at adapting crops to climate, as is shown by studying the method we have suggested. It is quite distinct from pure meteorology and has a place as a separate branch in the group of biological sciences which are applied to agriculture, having many interesting points of connection with genetics and rural economy.

AGRICULTURAL CLIMATOLOGY OF AUSTRALIA.

There appeared in the *Quarterly Journal of the Royal Meteorological Society*, October, 1920,¹ a very complete and interesting paper by Dr. Griffith Taylor, associate professor of geography in Sydney University, dealing with the climate of Australia in its relation to agriculture. Some of the more important facts brought out in Dr. Taylor's paper are herewith briefly summarized.

Australia has a lower average elevation than any other continent and is characterized by a greatly diversified climate. Rainfall is the chief factor governing settlement and agriculture and varies from 40 to 50 inches or more in limited areas along the northern, eastern, and southern coasts, to less than 10 inches throughout much of the interior of the country. Generally speaking, there are four major rainfall regions—summer rains in the north, or the tropical portions of the continent, winter rains in the south, a rather uniform rain region in the east, and an arid region in the interior and middle west.

In more than one-third of the continent drought is a permanent condition, while one-half of it receives practically no rain for six months of the year. It is the border land between the arid region and moist districts, where damaging drought is frequent and much feared, for here lies the main wheat belt. As regards the inland portion of South Australia, drought occurs about once in three years. Considerable attention has been given to irrigation. It is difficult to determine the lowest limits of rainfall which admit of profitable agriculture in Australia without irrigation. In much of the wheat belt only one-third of the area is under wheat at a time; the dry farming methods of fallowing and careful tilth are practiced and become increasingly important as the arid area is approached.

The definition of dry farming varies in different sections. In South Australia, a region receiving less than 18 inches of rainfall a year, is classed as dry, while in New South Wales, a region receiving even 25 inches, is so classed. An important factor in this connection is evaporation; it has been stated that every 3 inches of evaporation requires 1 inch of rain additional as an offset, so that 15 inches of rain in the southwest of New South Wales is equivalent to 20 inches in the northwest portion.

Wheat is by far the most important crop in Australia. It is grown principally on the southern plains between the Blue Mountains and the interior desert, along a narrow belt in the comparatively moist, cool portions of the country. Its climatic limitations are indicated by the absence of the crop in the northern tropical portions and also in the moister coastal belt of the southeast. The primary climatic control is rainfall, but it is not the annual total so much as the seasonal distribution. For good yield it is essential that sufficient moisture be received in the early autumn (April-May), when plowing and seeding are in progress, and again in the spring (September-October), when the plants are heading and flowering. With these requirements realized, Australia is assured of a fine wheat crop.

In the early stages of wheat production in that country mistakes were made and corrective progress was slow. At first it was thought that abundant moisture was essential, and cultivation was confined to the wetter, coastal country, with its annual rainfall of 30 to 40 inches, but the results were disappointing. Later it was discovered that the drier, interior districts were more suitable for this plant, which altered the situation very happily. The bulk of the crop is now grown where the annual rainfall is less than 25 inches, and in some sections wheat is grown where rainfall is very light. It has been stated that on some well-worked, fallowed land good crops have been gathered when rainfall was less than 5 inches.

The next crop in importance is hay. In most countries hay consists chiefly of meadow and other grasses, but in Australia a very large proportion of it is comprised of wheat and oats. Crops originally sown for grain are frequently cut for hay owing to the fact that the outlook

¹ Vol. XLVI, pp. 331-355.

for grain is not satisfactory. For example, in the drought year of 1914 nearly 1,000,000 acres were cut for hay in New South Wales instead of the normal 150,000 acres.

The distribution of oats differs considerably from that of wheat, the chief producing region being found where the temperature is about 5° cooler than in the principal wheat districts and the rainfall 7 inches heavier. Sugar is confined to the well-watered east coast and is derived almost entirely from cane. The temperature range under which sugar cane is grown is very considerable, varying from 68° to 78° F., but the necessity for a rainfall exceeding 40 inches confines production to the coast section.

The principal stock industry of this country is raising sheep, and here again rainfall is the control. Ninety per cent of the sheep of Australia are found in the south-eastern third of the continent, and the number grazed in a region receiving less than 10 inches of rain is insignificant, while there are practically no sheep where the average temperature exceeds 77°. There is a close relation between the distribution of sheep and rainfall. With an annual fall of 8 inches, about 20 can be grazed per square mile; with 20 inches, 180 may be maintained; while with 35 inches, the number has increased to 400 per square mile. With rainfall greater than 35 inches, however, there is a rapid diminution in the number of sheep raised, and where 50 inches or more of rainfall are received no sheep are found. The cattle industry is of not nearly so great importance as that of raising sheep and in many of the cooler regions where sheep are raised cattle also graze, but as a rule the latter are found to thrive in the wetter localities.—J. B. K.

WEATHER AND THE YIELD OF TEA.

The influence of temperature, rainfall, and humidity on the yield of tea during 1918, 1919, and 1920 is discussed briefly by C. R. Harler in *Indian Tea Association Science Department Quarterly Journal*, 1921, No. 1, pp. 28-31.

A warm and moist atmosphere is essential for good-sized leaves. An abundant rainfall is necessary, although excessive rainfall causes a water-logged condition of the soil that reduces the leaf yield and weakens the plants.

The normal mean temperature during the hot weather in Assam is about 82.5° F., the normal relative humidity 94 per cent, and the rainfall 16 to 20 inches or more each month. A rise in temperature is usually accompanied by a lowered daytime humidity, which causes a slow development of the leaves. In the latter part of the summer of 1919 there was a considerable increase in temperature, while the relative humidity fell to 75 per cent. A fair amount of rain was received, but "the fall was mostly at night, so that its full effect in raising the humidity was lost." These conditions unfavorably affected the growth of the leaves.—J. W. S.

INCREASING LENGTH OF FROST-FREE PERIOD ON WISCONSIN CRANBERRY BOGS BY SANDING.

J. WARREN SMITH, Meteorologist.

While in charge of the Cranberry Experiment Station near Cranmoor, Wis., Mr. O. G. Malde made a very complete and extensive record of temperature on marsh soils. The period of observation was from 1906 to 1916, inclusive. In a recent statement of some of the results of a study of these records, Mr. Malde says:

Temperature data recently compiled as a summary of 11 seasons of observations at the Cranberry Experiment Station (1906 to 1916, inclu-

sive) show that there is an average of 58 days between the last spring and first fall frost (June 25 to August 22) over unsanded bog, as against 118 days between last spring and first fall frost over sanded bog. This represents a gain of 95 per cent in length of frost-free season on sanded bog over that on unsanded bog. The item of sanding, therefore, greatly reduces frost hazards and conserves the water supply by eliminating the need for the frequent flooding to protect against summer frosts. Sanding also permits and, in fact, requires deeper and better drainage, and is an insurance against fires on a bog in dry times. Sanding, together with thicker setting of plants, reduces labor and expense of weeding, besides insuring earlier cropping on the bog.

These statements are in harmony with the observations made by Prof. H. J. Cox of the Weather Bureau, as published in Bulletin T., U. S. Weather Bureau, "Frost and Temperature Conditions in the Cranberry Marshes of Wisconsin," published in 1910.

THE SEASONAL MARCH OF THE CLIMATIC CONDITIONS OF A GREENHOUSE, AS RELATED TO PLANT GROWTH.¹

By EARL S. JOHNSTON.

[Author's abstract.]

The study here reported was undertaken to measure and integrate the climatic conditions of a greenhouse by means of various measurements taken from standard plants, as these conditions varied throughout the year, and also to measure and integrate these same environmental conditions in terms of instrumental data, to prepare for an analysis of such an environmental complex and an interpretation of the plant values by means of the instrumental ones.

The general method employed by McLean was followed. Buckwheat plants (approximately alike at the start, when they were small seedlings) were grown for four-week exposure periods during a total time period of 13 months. A new period began every fortnight. The plants were grown in solution culture and the chemical surroundings of the roots were practically the same in all cases. Such culture plants are considered as integrating instruments for measuring the climatic conditions, as these effect plant processes. Measurements of stem height, dry weight, leaf area, and transpiration were made at regular intervals as "readings" of these "instruments." Simultaneous measurements of evaporation, radiation, and temperature were also obtained. These plant and instrumental measurements were made from two series of tests, one conducted under the ordinary conditions of an unshaded greenhouse at Baltimore, the other within a cheesecloth inclosure in the same greenhouse. Most of the measurements were recorded every week and weekly data are presented, but this paper deals mostly with the four-week data, and mainly with the exposed series.

The seasonal march of the four-week plant growth rates may be summarily described as follows: The rates for stem elongation, for dry-weight increase and for leaf-area increase had high summer values and low winter ones. These values increased during the spring and decreased during the autumn. The rates of transpirational water loss varied throughout the year in a similar manner, but they showed low values about the summer solstice. The rates of stem elongation also showed remarkably low values for a period about the time of the summer solstice. The approximate annual ranges (ratios of maximum to minimum) were as follows: Rate of stem elonga-

¹ Botanical contribution from the Johns Hopkins University No. 59. A dissertation submitted to the Board of University Studies of the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy, June, 1917.

Delay in publication has been brought about by the unsettled conditions existing during and immediately following the war.

² Reprinted from *Bulletin No. 245*, Univ. of Md. Agr. Exp. Sta.

tion, 2; rate of dry-weight increase, 8; rate of leaf-area increase, 5; rate of transpirational water loss, 9.

Four derived plant values are considered: (1) Those obtained by averaging the four-week rates of increase in dry weight and in leaf area, (2) the four-week rates of transpirational water loss per unit of total dry weight, (3) the four-week rates of transpirational water loss per unit of leaf area, and (4) the four-week rates of dry weight increase per unit of leaf area. The first of these derived values (which does not differ fundamentally from either of the two values that were averaged) gives what may be called the weight-area index of plant growth. Its maximum is seven times as great as its minimum. The four-week rates of transpirational water loss per unit of total dry weight (water requirement) seem to bear no general relation to the march of the season. The transpiration rates per unit of leaf area (areal coefficient of transpiration), though resembling those of the water requirement in some respects, show an indication of a seasonal march with low midsummer values. The four-week rates of dry weight increase per unit of leaf area (areal coefficient of dry-weight increase) exhibit a general similarity to those of transpiration per unit of leaf area, but show more clearly a seasonal march with high summer and low winter values.

The greenhouse climate during the year of this study, as measured by the plant processes mentioned above, appears to have been most favorable to the general growth of these plants during two separate periods, one in early summer (April 10 to May 22) and one in late summer (July 3 to September 11). The most favorable periods for stem elongation occurred for the two four-week periods ending May 22 and September 25. The period extending from May 22 to July 31 was very favorable for dry-weight production and increase in leaf area. It is also clear that the climatic efficiency for producing growth was lowest during the winter period (about November 20 to about February 26). Even with the usual application of artificial heat, the winter efficiency for plant growth remained very low.

The evaporating power of the air, as measured by the white spherical porous-cup atmometer, showed somewhat higher and more uniform values for the winter than for the summer. The most pronounced seasonal fluctuation was shown by indices of total radiation obtained with the radiometer. There is fairly good agreement between these radiation values and those of actual sunshine duration, for corresponding periods. Maximal summer values occurred at approximately the same time for both indices, but the minimum radiometer value occurred several weeks earlier than did the minimum duration value. The temperature values (average daily mean and average daily range for each four-week period) showed a rather decided seasonal variation, with high summer values and low winter ones.

The climatic efficiency values within the cheesecloth chamber in the greenhouse appear, in general, to have been lower than those in the unshaded greenhouse, the exceptions being the values for stem height and for leaf area, for periods about June 21. The evaporation and radiation indices for the sheltered series are much lower than those for the exposed series. Very little difference

is to be noted between the corresponding temperature values for the cheese-cloth chamber and for the unshaded greenhouse.

While the interpretation of the plant values in terms of those derived from the instruments offers many difficulties, nevertheless the following striking features of this environmental complex that are registered in the records of both plants and instruments, may be mentioned: (1) Fairly good agreement exists between the daily mean temperatures and the transpiration rates, while none of the other plant values shows such agreement with the mean temperatures. (2) The summer values for average daily temperature range and those for transpiration vary in the same direction. (3) Along with high evaporation rates in late summer occur high temperature, radiation and transpiration values, but low values for the rates of increase in dry weight and in leaf area. (4) A rather general agreement is to be observed between the radiation values and the areal coefficients of weight increase and of transpiration, but there is no very marked agreement between the radiation values and those of the water requirement. (5) With the exception of the water requirement of the plants and the evaporating power of the air, the values here studied (both plant and instrumental) exhibit low magnitudes for the winter period.

Where stem elongation is used as a criterion of growth, measurements taken after an exposure period of two weeks appear to be as satisfactory as those taken after a period twice as long. It appears that the climatic conditions effective during the first two weeks of these tests predetermined, in a great measure, the rates of stem elongation for the succeeding two-week period in each case, so that the climatic fluctuations of the second two-week period were practically ineffective to produce differences. These buckwheat plants appear to have been generally much more sensitive to climatic influence during the first two weeks than during the second.

For the rate of stem elongation, and possibly also for that of transpiration, it appears that a period of low values occurs about the summer solstice.

CITRUS ORCHARD HEATING.

The January freeze in southern California gave orchard-heating apparatus a severe test. Commenting upon the results the *Los Angeles Examiner* in a recent issue prints the following:

Fruit Growers' Supply Committee fixes upon standardized device for preventing frost losses.

One hundred per cent citrus crops in California annually through the conquering of frost is the aim of the Fruit Growers' Supply Committee. Factors crystallizing toward that end began to shape themselves at a meeting of the orchard-heating committee in the Consolidated Realty Building yesterday afternoon.

At least two definite points resulted from the discussion. These were (1) that the heating of citrus orchards is not only advisable but essential as a protection against frost; (2) that a standardized heater at a lesser cost than those now on the market is equally as essential.

The Fruit Growers' Supply Committee is described by its officers as the buying organization for the California Fruit Growers' Exchange, through which the products of affiliated growers are sold. The heating committee is a subcommittee of the general board of the parent organization.

NOTES, ABSTRACTS, AND REVIEWS.

THE FUNDAMENTAL EQUATIONS IN THE HYDROLOGY OF RIVER REGIONS.

By KARL FISCHER.

[Abstracted from translation made by W. W. Reed from *Meteorologische Zeitschrift*, 1921, pp. 331-336.]

The author discusses the fundamental equations in the hydrology of rivers. These equations are necessarily based upon one's conception of the relative quantities of water vapor originating over oceans and land areas, respectively. Since the amount of water vapor carried by ocean winds that pass over continental areas is not susceptible of definite determination and, moreover, since the moisture that falls as rain on land areas may be reevaporated, not only once but several times, the discussion of the relations between these quantities and the run-off from land areas must naturally take on an academic character.

The author starts with the simple proposition,

$$N = A + V \quad \dots \dots \dots (1)$$

where N is the amount received at the surface of the ground, A is the run-off, and V is the evaporation.

His second step is to consider the quantity of water vapor carried by the air which passes over any watershed.

The author distinguishes by M the amount of water vapor coming, in the last analysis, from the sea; over against this is placed the run-off, A , as before, and, E , the amount of water vapor escaping (evaporating) into the air, so that his fundamental equation now becomes

$$M = A + E \quad \dots \dots \dots (2)$$

The question as to the relative amounts of vapor transported from the ocean to the land, and vice versa, is discussed. The author comments upon the view of Brückner on this and other closely related subjects, and the latter makes a rejoinder. The translation of both Fischer's article and Brückner's rejoinder are filed in the Weather Bureau Library, where they may be consulted by those interested.—A. J. H.

THE VARIABILITY OF TEMPERATURE IN SUCCESSIVE MONTHS AND THE PERIODIC OSCILLATIONS OF ANNUAL TEMPERATURE IN GERMANY.

By FRANZ BAUR.

[Abstract of Doctor's Dissertation, translated by W. W. Reed from *Meteorologische Zeitschrift*, April, 1922.]

For this investigation there were taken as a basis temperature observations for the period of 50 years from 1870 to 1919, inclusive, at the following 10 stations in Germany: Königsberg (Prussia), Berlin, Hamburg, Breslau, Leipzig, Munster (Westphalia), Bamberg, Frankfurt-on-the-Main, Munich, Karlsruhe (Baden).

From the monthly means of temperature for these 10 stations there was calculated the mean temperature for Germany in each month of the 50 years and the departure from the 60-year mean. For the representation of the temperature contrasts between successive months there was introduced the concept of "month-to-month change in temperature," the difference in the temperature departures of two directly successive months. The mean value of a series of such differences was called "month-to-month variability." In Germany the month-

to-month variability amounts on an average to 1.7°C . It shows an annual and a semiannual oscillation. The annual oscillation is a result of the annual march of the "mean" variability of the monthly means of temperature, which is greater in winter than in summer; the semiannual oscillation is caused by the annual march of temperature itself, since the minima of the double wave of month-to-month variability occur where the temperature shows a maximum or a minimum. To the annual march of month-to-month variability there corresponds also the annual march of tendency to maintain the sign of temperature departure. This shows a considerable amount of tendency (not accidentally caused) only from February to March. This tendency to maintain temperature departure from February to March is plainly an accompanying circumstance to the phenomenon that in Germany the character of the winter with reference to temperature extends in most cases to the following March. Especially does this prove true for mild winters. In the years 1870 to 1919, inclusive, in 78 per cent of the cases (in Germany) a too-warm March followed a too-warm winter.

By means of Fourier's analysis investigation was made as to whether the month-to-month variability shows periods of more than a year's duration. There were calculated the amplitudes of 52 different periods, of which the shortest was 1.6 years, while the longest period was 20 years. For the determination whether those periods for which there resulted the greatest amplitudes are actually present, there was employed Schuster's test, as well as a phase test given by Professor Ansell. It resulted that periods of month-to-month variability in temperature of 2, 2.5, 3.4, 4.5, and 5.5 years duration are very probably real.

From the definition of "month-to-month variability" it could be demonstrated by a simple mathematical deduction that it can contain true periods only when the course of the temperature itself contains true periods, and that the temperature periods must be twice as long as the periods of month-to-month variability. As the double annual wave of month-to-month variability is a result of the annual temperature wave, so to the periods of month-to-month variability of 2, 2.5, 3.4, 4.5, and 5.5 years there correspond temperature periods of approximately 4, 5, 7, 9, and 11 years. In order to make a decision as to the reality of the periods the temperature departures were subjected to further analysis. It could be established conclusively that in the temperature course in Germany for the years 1870 to 1919 there are contained actual periods with duration of oscillation nearly 2.5, 4, 7, and 11 years. The analysis of the annual temperature departures gave the greatest amplitudes for an 18-year period and a 36-year period. The observational data is for a period too short to establish with certainty the reality of periods so long, still the close agreement of the 18-year period with the Chaldean period of lunar eclipses and with the period of the movement of the moon's nodes and the agreement of the 36-year period with the well known Brückner period make the reality of these periods quite probable.

In the period from 1870 to 1919 the maximum of the 11-year temperature period falls two-thirds of a year after the sun spot maximum.¹

By ascertaining the amplitudes and the phases of the well-known temperature periods for shorter lengths of

¹ It is generally recognized that terrestrial temperatures are at a minimum at times of sun-spot maximum.—EDITOR.

time and by extrapolation beyond the last observation year (for the time being) there resulted the probability of a prediction of the thermal character of the following observation period of from 2 to 3 years, with the restriction that there is limitation to the distinction of the following chief types: Very warm—warm—normal—cool—cold. In order to test the utility of such predictions, the necessary calculations were carried out for each year of the period from 1900 to 1918, and in each of the 19 cases predictions were made for one, two, and three years. Although the analysis could not be carried out strictly since, on account of the short period of observation it was not possible to take an exact account of the long periods, still there were among the 57 predictions only 6 (16 per cent) that were found contrary to the temperature characteristics actually met with. A comparison of the calculated temperature departures with the observed departures by means of the "correlation method" showed that the probability of an "accidental" agreement of the previously calculated temperature departures with the actual departures is less than 1/10,000,000. The good agreement between experience and prediction permits us to view as correctly made the assumption that the agreement is entirely general and not only in the limits of the observational data at hand. Therewith the difficult problem of the prediction of the thermal character of the coming years is brought nearer relative to the principle of solution. It depends on the exceedingly important demonstration that in the temperature course in Germany there are contained actual periods of long duration.

The extension of the same investigation to other meteorological elements, as well as to the subdivisions of the year, is naturally very obvious. The execution of these investigations and their application I reserve for a further work already undertaken.

FORECASTING THE WEATHER, PARTICULARLY STORMS, FROM PILOT-BALLOON OBSERVATIONS.

By J. LACOSTE.

[Abstracted from *Comptes Rendus*, November 21, 1921, pp. 997-999.]

During more than two years in the meteorological service of the third army, having practised soundings by pilot-balloons every four hours day and night, the author tried to find a relation between the forms of

graphs of the horizontal projection of the course of the balloon, the data of synoptical weather charts, and the behavior of the barometer. From this comparison, he has deduced some conclusions which may be helpful in forecasting:

Different types of soundings have been classified as follows:

(1) Soundings at constant direction—those in which the lower and upper winds maintain sensibly the same direction.

(2) Soundings at an abrupt angle—the upper winds suddenly taking directions, generally from the west, contrary to those of the lower winds. Two layers of air, one gliding over the other without friction.

(3) Turning sounding—those in which the wind changes progressively its direction with altitude. For example, the lower winds being east or southeast, the upper winds becoming south-southwest and west with altitude. Two layers of air mutually penetrating.

(4) Soundings in which the winds of the layer 0 m. to 2,000 m. change direction rapidly with time and are from many different directions for neighboring stations.

(5) Soundings indicating winds weak and variable in direction up to great heights.

From the point of view of forecasting, the author makes the following remarks:

(1) The soundings of the first class are characteristic of cyclonic areas or the edges of anticyclones. The direction of the winds permit finding the direction of the center of the depression; it is usually found from the direction of the winds about 1,000 m. The changing of the general direction of the winds with time indicates the displacement of the center and permits determining the direction of this displacement.

(2) The soundings at an abrupt angle announce a distant depression. If successive soundings show the angle to be at higher and higher altitudes the depression is not to be feared. If the angle falls progressively, the depression is dangerous, the upper winds grow in force, the barometer falls. The upper winds appear to come from the low center.

(3) Soundings turning from east or southeast to south, southwest, and west with altitude are precursors of storms. Not only do they indicate a low area invading France from the southwest (Spain, Gulf of Gascony), but if the lower winds attain 4 or 5 m. one should look for the storm in 24 hours at the place of the sounding or in the neighborhood. In winter there will be snow.

(4) Soundings of the fourth class characterize the secondary depressions, barometric pockets. They show that in similar circumstances, only the winds of the 0-2,000 m. layer experience rapid variations with time. Above them one finds the winds that direct the principal depression. Similar soundings are also the precursors of storms in summer and snow in winter.

(5) Soundings of the fifth class are made on high anticyclonic plateaus or toward the center of vast cyclonic areas.

—G. F. H.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING APRIL, 1922.

By IRVING F. HAND, Temporarily in Charge.

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, 48:225.

From Table 1 it is seen that direct solar radiation intensities averaged above normal for April at Washington, and close to normal at the other two stations. Pyrheliometric observations have been discontinued at the Santa Fe station on account of the removal of the Weather Bureau office to a site poorly adapted for this work.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged above the April normal at Washington and slightly below at Madison, Wis.

Skylight polarization measurements made on three days at Washington give a mean of 56 per cent, with a maximum of 59 per cent on the 24th. These are about average April values. The value of 70 per cent on the 18th is the highest ever observed at Madison in April. The monthly mean of 60 per cent is about normal.

TABLE 1.—Solar radiation intensities during April, 1922.

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.												
Sun's zenith distance.												
Date.	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.	
	75th meridian time.	Air mass.										Local mean solar time.
		A. M.					P. M.					
		e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0		e.
Apr. 3.....	mer.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.	
10.....	12.68			0.84	1.09						3.63	
12.....	5.79						1.04	0.84	0.70		9.83	
13.....	7.29	0.52	0.63	.73							4.95	
20.....	3.48	.85	.91	1.00	1.18		1.29				7.29	
24.....	2.74	.82	.94	1.10	1.27	1.51					2.06	
Means.....		.75	.84	.92	1.17	(1.16)	(.84)	(.70)			2.26	
Departures.....		+.06	+.09	+.03	+.10		+.08	-.05	-.04			

* Extrapolated.

TABLE 1.—Solar radiation intensities during April, 1922—Continued.

Madison, Wis.												
Sun's zenith distance.												
Date.	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.	
	75th me- rid- ian time.	Air mass.										Local mean solar time.
		A. M.					P. M.					
		e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0		e.
Apr. 1.....	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.	
7.....	11.38		1.05	1.17	1.29			1.23			3.45	
15.....	5.16				1.13						8.18	
18.....	3.45			1.14	1.33	1.48					5.36	
20.....	3.45				1.19						3.63	
22.....	3.81			.98	1.16	1.36					3.99	
23.....	5.16				1.09						4.95	
Means.....			(1.05)	1.10	1.20		(1.23)					
Departures.....			±.00	±.00	-0.03		-0.01					

Lincoln, Nebr.												
Apr. 7.....	6.02				1.14		1.09	0.85	0.65	0.45	7.04	
11.....	4.75						1.31	1.12	1.03		4.75	
14.....	6.27						1.32	1.16	.95		5.16	
15.....	6.27		0.99	1.12	1.28	1.47	1.14	.94	.77	.60	6.50	
19.....	3.15			1.19	1.37		1.27	.95			2.49	
20.....	5.16			0.90	1.07						7.04	
21.....	6.27	0.68	.79	.99	1.20	1.36	1.13	.94	.78	.65	6.50	
22.....	5.36	.67	.80	.95	1.14	1.37					8.18	
29.....	6.50		.78	.91							3.63	
Means.....		(.68)	.84	1.01	1.20		1.21	.99	.84	.59		
Departures.....		-.06	-.01	±0.00	-0.02		+.03	+.01	+.01	-.03		

TABLE 2.—Solar and sky radiation received on a horizontal surface.

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Apr. 2.....	345	251		-45	-126		-1907	-1522	
9.....	415	296		+8	-97		-1851	-2197	
16.....	367	445		-58	+32		-2257	-1970	
23.....	531	479		+87	+45		-1651	-1652	

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION, AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, D. C.]

NOTE.—Owing to delay in transmission, the data from South America will be included in the next issue of the REVIEW.—EDITOR.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was near the normal at land stations on the coasts of Canada and the United States and at Swan Island, West Indies. The average was slightly higher than usual in Porto Rico, the Bermudas, and Azores, while it was somewhat below normal in the British Isles. The North Atlantic or Azores HIGH varied greatly during the month, as at Horta the average barometric reading for the first 15 days was 29.88 inches and for the last half, 30.49 inches.

Judging from vessel reports received, there was less fog than usual over the Grand Banks and steamer lanes, while it was recorded on 5 days at the 1 p. m. observation at London.

The number of days with winds of gale force was somewhat higher than usual over the middle section of the southern steamer lanes. In the square between latitude 40° to 45° N. and longitude 35° to 40° W., gales were reported on 8 days, which is considerably in excess of the normal as shown on the Pilot Chart.

On the 1st there was a well developed LOW central near latitude 44° N. and longitude 37° W., with gales from the west in the southerly, and from the north in the westerly quadrants, while snow was observed near the center. This disturbance moved but little during the next 24 hours, remaining about the same in extent and intensity. Storm logs follow:

American S. S. Eastern Dawn:

Gale began on March 31, wind SW. Lowest barometer 28.77 inches at 8 p. m. on the 2d, wind N., 9, in latitude 43° 46' N., 39° 51' W. End of gale on the 4th, wind NW. Highest force of wind 10; shifts SSW.-NNW.

British S. S. Canadian Leader:

Gale began on the 2d, wind NNW. Lowest barometer 28.92 inches at 10.30 p. m. on the 2d, wind N., 9, in latitude 44° 06' N., longitude 40° 04' W. End on the 2d, wind NNW. Highest force of wind 9; steady from NNW.

On the 2d there was a second disturbance with its center a short distance south of Sable Island and moderate to strong gales prevailed over the region between the sixtieth meridian and the American coast, the storm area extending as far south as the thirtieth parallel. This depression drifted slowly eastward during the next seven days and on the 9th was central somewhere near latitude 50° N., longitude 30° W., although there were not enough reports from northern waters for an accurate determination. Storm logs follow:

American S. S. Susquehanna:

On the 2d in latitude 40° 43' N., longitude 53° 57' W., barometer began to fall from 29.66 inches at 2 a. m., reaching 29.06 inches at 11 a. m. Light variable breeze shifting from W. to E., and finally steady at NE.

American S. S. Devolante:

Gale began on the 2d, wind WSW. Lowest barometer 29.63 inches at 2 a. m. on the 3d, wind W., in latitude 31° 06' N., longitude 54° 54' W. End on the 4th, wind NW. Highest force of wind 10; shifts WSW.-W.

American S. S. Eastern Leader:

Gale began on the 2d, wind E. Lowest barometer 29.30 inches at noon on the 2d, wind E., 8, in latitude 41° 54' N., longitude 58° 49' W. End on the 6th, wind NNW. Highest force of wind 9, N.; shifts E.-NE.-N.-NNW.

British S. S. Epsom:

Gale began on the 1st, wind SW. Lowest barometer 29.85 inches at 8 p. m. on the 1st, wind SW., in latitude 33° 59' N., longitude 66° 15' W. End on the 3d, wind N. Highest force of wind 10; shifts SW.-W.-WNW.

American S. S. West Celina:

Gale began on the 5th, wind SW. Lowest barometer 29.87 inches at noon on the 5th, wind SW., 7, in latitude 40° 43' N., longitude 35° W. End on the 7th, wind SW. Highest force of wind 9; shifts not given.

British S. S. Kenbane Head:

Gale began on the 7th, wind NE. Lowest barometer 29.26 inches at 4 a. m. on the 8th, wind NE., 10, in latitude 48° 25' N., longitude 35° 10' W. End on the 10th, wind E. Highest force of wind 10; shifts ENE.-NE.

On the 3d there was also a moderate disturbance off the coasts of France and England. Storm log:

British S. S. Cassis:

Gale began on the 2d. Lowest barometer 29.40 inches at 5 p. m. on the 3d, wind WSW., 8, in latitude 45° 20' N., longitude 9° 10' W. End on the 4th, wind N. Highest force of wind 9; shifts SW.-W.-WNW.

On the 10th and 11th there was a depression of limited extent north of the Azores that afterwards developed into the disturbance shown on Charts VIII to XI, for the period from April 12 to 15, inclusive. Storm logs follow:

British S. S. Hartington:

Gale began on the 10th, wind W. Lowest barometer 29.34 inches at midnight on the 12th, wind WSW., 10, in latitude 39° 08' N., longitude 30° 05' W. End on the 17th, wind SW. Highest force of wind 11, N.; shifts WSW.-W.-WSW.

British S. S. Nucula:

Gale began on the 13th, wind NNE. Lowest barometer 29.52 inches at 8 a. m. on the 13th, wind NNE., 8, in latitude 46° 15' N., longitude 28° W. End on the 14th, wind N., 6. Highest force of wind 9, NNW.; shifts NNE.-N.-NNW.

American S. S. West Caddoa:

Gale began on the 12th, wind W. Lowest barometer 29.66 inches at 8 p. m. on the 12th, wind W., 10, in latitude 38° 39' N., longitude 37° 59' W. End on the 13th, wind NE. Highest force of wind 12; shifts W.-NNW.-N.

American S. S. Colthraps:

Gale began on the 13th, wind NNE. Lowest barometer 29.21 inches at 7 a. m. on the 14th, wind NNE., 8, in latitude 48° 40' N., longitude 17° 45' W. End on the 15th, wind NW. Highest force of wind 10, N.; shifts not given.

American S. S. West Kasson:

Gale began on the 14th, wind S. Lowest barometer 29.65 inches at 2 a. m. on the 16th, wind S., 10, in latitude 45° 25' N., longitude 30° 05' W. End on the 16th. Highest force of wind 10, S.; steady from S.

At 7 p. m. on the 10th American S. S. *Maracaibo* encountered thick fog in latitude 36° 43' N., longitude 73° 05' W.

On the same day the observer on board the Honduran S. S. *Hibueras* reported a strong southerly gale with rough sea; Greenwich mean noon position, latitude 27° N., longitude 88° 10' W.

On the 16th and 17th heavy weather prevailed over a large portion of the ocean between the thirtieth and fiftieth parallels. Storm logs:

American S. S. Edgehill:

Gale began on the 15th, wind SW. Lowest barometer 29.18 inches at 8 p. m. on the 15th, wind WSW., 9, in latitude 37° 30' N., longitude 60° W. End on the 16th, wind NNW. Highest force of wind 10; shifts 6 points.

American S. S. Noccalula:

Gale began on the 16th, wind NNW. Lowest barometer 29.43 inches at 6:30 p. m. on the 16th, wind NNW., 9, in latitude $40^{\circ} 25' N.$, longitude $49^{\circ} 18' W.$ End on the 17th, wind NNW. Highest force of wind 9; shifts E.-ENE.-NE.-N.-NNW.

From the 18th to the 23d, with a few exceptions, moderate weather with uniformly high pressure prevailed over the ocean.

From the 19th to the 21st a few reports were received from vessels that experienced winds of gale force near the fortieth parallel, between the fiftieth meridian and the American coast.

On the 19th a strong "norther" prevailed off the coast of Mexico as shown by following storm log:

American S. S. Devolante:

Gale began on the 19th, wind NW. Lowest barometer 30.08 inches at 1 a. m. on the 19th, wind NW., 8, in latitude $23^{\circ} 25' N.$, longitude $97^{\circ} 15' W.$ End at 2 a. m. on the 20th, wind NE. Highest force of wind 9; shifts NNE.-NW.

From the 24th to the 26th there was a moderate depression that moved slowly eastward along the fortieth parallel; it was central on the former date near the sixty-third meridian, and on the latter, not far from the fifty-third.

From the 24th to the 28th there was also a disturbance off the coasts of France and England, the storm area extending as far west as the twenty-second meridian on the 26th. Storm log follows:

Swedish S. S. Stockholm:

Gale began on the 26th, wind NW. Lowest barometer 29.85 inches at 10:36 a. m. on the 26th, wind NW., 7, in latitude $56^{\circ} 03' N.$, longitude $20^{\circ} 17' W.$ End on the 27th. Highest force of wind 10; shifts not given.

On the last two days of the month moderate to light winds with high pressure and slight gradients were the rule over the eastern section of the ocean. There was however during this period a low central near St. Johns, Newfoundland, although no gale reports were received from vessels in the vicinity.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

The most noteworthy feature of the weather of the North Pacific Ocean during April was the abnormally high pressure which prevailed over the eastern part of the ocean between the 9th and 13th. During this period barometer readings exceeding 30.50 inches were recorded daily and on the 10th and 11th the S. S. *Canadian Prospector* reported by radio readings of 30.84 inches. The center of the anticyclone was on these days located near $40^{\circ} N.$, $140^{\circ} W.$

It may be remarked in this connection that the unseasonably cold weather which prevailed over the western United States during the greater part of April culminated during the week following the development of this unusually high pressure.

The weather of the month was stormier than usual, especially west of the one hundred and seventieth meridian, west longitude. This was particularly true of the period from the 5th to the 9th, when vessels on the northern steamer route between the meridians of $160^{\circ} E.$ and $170^{\circ} W.$ experienced very heavy weather, occasioned probably by the uniting of a series of three depressions which passed over Japan on the 4th and 5th (Asiatic time). The combined depression developed into a deep cyclone which moved northeastward over Bering Sea on the 6th and 7th (American time) and dis-

appeared to the northward of Alaska on the 8th. On the morning of the 7th the barometer at St. Paul, Pribilof Islands, registered 28.96 inches.

The month opened with a deep cyclone occupying the region of the Aleutian Islands and causing moderate to strong westerly gales along the northern steamer route. The barometers at Dutch Harbor and St. Paul registered 28.56 inches on the morning of the 1st. The North Pacific anticyclone was somewhat to the south of its usual position with a central isobar of 30.20 inches. This is slightly below the normal for April. Pressure was rising, however, in the western part of the ocean, apparently as a result of the eastward movement of anticyclones from Asia and on the 5th the barometer at Midway Island stood at 30.34 inches, 0.20 inch above normal. By the same date, also, the large cyclone over the Aleutians had broken up into several smaller depressions which had moved eastward to the continent. These conditions were succeeded by the depression of the 7th-8th over Bering Sea and the strong anticyclone of the 9th-13th, already referred to. The latter, it should be stated, caused fresh to strong northwesterly gales off the American coast.

On the 14th a fresh depression developed over the Aleutian region and moved slowly eastward, being still central over the Gulf of Alaska on the 20th. On the latter date another and vigorous cyclone appeared over the western Aleutians, and thereafter until the close of the month this region was occupied by low-pressure systems of varying intensities. The lowest pressure recorded was 28.70 inches at Dutch Harbor on the evening of the 29th.

In Asiatic waters some 22 depressions were charted during the month by the Imperial Marine Observatory at Kobe. For the most part these were devoid of any unusual features. The most extensive one was that which occupied the region of the Yellow and Eastern Seas on the 24th and 25th.

In so far as shipping was concerned, the weather conditions affecting the western portion of the northern steamer routes from the 5th to the 9th were the most important. Several vessels were involved in the gales of this period, among them the American S. S. *Coaxet*. This vessel, under command of Capt. G. N. Hampson, Observer, E. J. Stull, was bound from Vancouver for Nagoya. According to Mr. Stull, the gale began on the evening of the 5th, wind S., force 7, barometer 29.75 inches and falling, weather overcast with rain and snow, heavy S. sea. During the 6th the barometer continued to fall until 1 p. m., when the minimum pressure of 29.16 inches was recorded. The *Coaxet* at this time was near $51^{\circ} N.$, $177^{\circ} W.$ At 4 a. m. of the 6th the wind had backed to S. by E. and strengthened to a fresh gale, with an increasing sea. At 10 p. m. the wind veered to S., force 9-11, barometer 29.20, high cross sea from S. and SSW., thick rain and fog. At noon the wind was S. by W., 11-8. At 4 p. m., SSW., 11, barometer 29.21, cloudy with heavy snow squalls; 8 p. m., SSW., 12, very heavy SSW. to W. sea. Vessel at this time hove to, head to sea. Height of waves conservatively estimated at 45 feet. After this time the barometer continued to rise slowly and the storm gradually abated. At 8 a. m. of the 7th the barometer was 29.92 inches, wind SW., 8-9, good visibility, high SSW. to W. sea.

The American S. S. *Pine Tree State* (since renamed the *President Grant*) was involved in the same storm on the 5th and 6th, Asiatic time. This vessel, under command of Capt. M. M. Jensen, Observer H. V. Van Dusen, sailed

from Kobe for Seattle on the 1st, and at noon of the 5th (G. M. T.) was in 47° N., 169° E. At 1 a. m. (S. M. T.) of that day, reports Mr. Van Dusen, the barometer was falling slowly, wind sluggish easterly, later veering to south. By noon the wind had increased to a fresh gale from SW. At 10 a. m. of the 6th the barometer reached its lowest point, 29.45 inches and the wind attained force 10, S. Conditions indicated to observers aboard the vessel that the storm was traveling eastward at the same speed as the ship, about 400 miles a day.

Pressure at Dutch Harbor was generally above normal from the 5th to the 19th, the average departure for this period being 0.20 inch. The highest pressure, 30.54 inches, occurred on the 12th. During the remainder of the month the average negative departure was about 0.65 inch. At Midway Island pressure was above normal generally throughout the month, the daily average excess being some 0.09 inch. Pressure at Honolulu averaged slightly below normal.

HURRICANE IN SOUTH PACIFIC OCEAN.

During the period extending from January 15 to 24, 1922, a hurricane prevailed in the western part of the South Pacific Ocean. Forming to the eastward of the Solomon Islands, probably sometime prior to the 15th, it moved on a west-southwest course, and on the 17th and 18th recurved about midway between the New Hebrides Islands and the coast of Australia. It thence moved to the southeastward, traveling at moderate speed, and passed between New Caledonia and Norfolk Island. On the 24th the center was somewhat to the north of New Zealand.

The following report of the hurricane has been received from the British S. S. *Waihora*, on voyage from Newcastle, N. S. W., to Nauru Island, located in about 1° S., 167° E. The correction for the barometer, an aneroid, is not known, but it is stated that the readings are probably below standard.

January 10.—8 a. m., cleared Newcastle in ballast. Experienced moderate to fresh easterly winds with slight sea to 15th. Fine and clear.

January 15.—Noon, lat. 16° S., long. $159^{\circ} 27'$ E. Bar. 29.64, ther. 78° . Wind freshening from SE. by E. (true). Rough sea, cloudy, fine. 4 p. m. Strong breeze, rough sea, cloudy, clear; bar. 29.56, ther. 77° . 6 p. m. Weather indications bad. Furling all awnings and battened down. Sunset coloring of clouds to westward a tawny or bronze color and streaked with broad patches of green of all shades.

8 p. m. Bar. 29.55, ther. 75° . Becoming squally. 12 p. m. Strong breeze from SE. by E. (true). Rough, increasing sea, heavy rain squalls, cloudy overcast sky.

January 16.—2:50 a. m. Wind still SE. by E., steadily increasing, with falling glass and increasing sea. Every indication that hurricane was approaching, with exception that the sea remained true to wind. Stood to westward.

4 a. m. Bar. 29.35, ther. 75° . Wind SE. by E., gale force, heavy rain squalls. Sea increasing and becoming confused; rolling heavily. Speed reduced to 5 knots owing to racing.

8 a. m. Bar. 29.31, ther. 75° . Strong gale SE. by E. Heavy driving rain squalls.

Noon. Bar. 29.14, ther. 74° . Heavy gale SE. by E. Heavy easterly sea making itself apparent, but main sea still true to wind.

4 p. m. Bar. 28.89, ther. 74° . Very heavy gale from SE. by E. Very heavy, confused, dangerous sea. Thick driving rain squalls of hurricane force.

8 p. m. Bar. 28.65, ther. 73° . Wind and sea still increasing with hurricane squalls. Wind veering SSE.

9 p. m. Bar. 28.60, vibrating wildly over a full tenth. Wind S.

10 p. m. Bar. 28.46.

10:11 p. m. Hurricane at its height.

11 p. m. Bar. 28.40.

12 p. m. Bar. 28.44 and steady, ther. 73° . Wind hurricane force, from SSW. Sea mountainous and confused. Wind force converting wave break into a stinging spindrift.

January 17.—4 a. m. Bar. 28.80, ther. 74° . Fierce gale with mountainous, confused sea.

8 a. m. Bar. 29.15, ther. 75° . Wind NW., gradually moderating and sea falling.

You will notice from above extracts that there was very little warning of an approaching hurricane.

The sunset sky was the most definite, along with the steadily falling barometer. There was a total absence of swell not accounted for by wind prevailing, possibly owing to intervening islands and reefs. I ran approximately 80 miles in a WNW. (mag.) direction, before the center of the storm passed, making my position at that time $15^{\circ} 1' S.$, $158^{\circ} 26' E.$ As I could not change the direction of the wind from SE. by E. (true) and could not increase speed owing to the light condition of the ship, I concluded that the center must pass over me. This I evidently only just avoided. The rapid fall in barometer, the wild vibrating, especially from 8 p. m. to 11 p. m., the sudden changes of wind from SE. by E. through S. to NW., the dull green patch of sky visible astern for a short time between squalls, seemed to indicate that the ship was very close to it. While no calm was experienced, there was just a sensible easing of wind force between 11:30 and 12 p. m., and a dense black pall seemed to almost touch the mastsheads. The S. S. *Bulga* (Australian Commonwealth Line) experienced this hurricane on 18th in vicinity of Cato Reefs.

A cyclonic storm in which the American schooner *Helen B. Sterling* was lost in $31^{\circ} 10' S.$ and $170^{\circ} E.$ on January 23 appears to have been the same gale and would indicate with *Bulga's* position the rate of progression.

The Italian cruiser *Libia*, proceeding from Suva to Sydney, crossed in front of the hurricane on the 17th-19th. Throughout the whole of the voyage, extending from the 16th to the 21st, the wind held between E. by S. and SSE., reaching force 10, SE. by S., on the 18th and 19th. The lowest barometer recorded at any Greenwich mean noon observation was 29.65 inches on the 18th.—*F. G. T.*

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

British Isles.—The rainfall of April was above the average for the period 1881-1915 nearly everywhere in the British Isles, the only exceptions being in the northwest of Great Britain.¹

Norway.—A violent snowstorm was experienced at Hammerfest on the 11th.¹

Russia.—RIGA, April 14.—Twenty thousand persons are affected by the flood of the Dvina river, caused by the damming of the river by the ice jam. * * *

Eight villages were reported under water, and thousands of inhabitants clinging to house tops were being rescued as rapidly as possible by boats. Army aviators dropped bombs on the clogged ice, somewhat relieving the congestion of the flood.—*Star-Gazette, Elmira, N. Y., April 14, 1922.*

France.—PARIS, April 11.—Navigation in the Seine through Paris was at a standstill to-day because of the abnormal rise of the river. Several neighboring municipalities were flooded, and some of them reported great losses of property and cattle.—*Associated Press, April 11, 1922.*

Switzerland.—Heavy rains in Switzerland at the beginning of the month caused a serious landslide near Le Bouveret (Valais) in the Rhone Valley.¹

Australia.—The dry spell which has been causing anxiety to farmers in some parts of Australia was broken toward the end of April by rains in South Australia and New South Wales.¹

Brazil.—The special message from Brazil states that rainfall was excessive over the northern region, the excess being on the average 180 mm. * * * but 300 to 600 mm. in certain stations. There were destructive floods in Amazonas, Ceara, and Alagoas States.¹

¹ The Meteorological Magazine, May, 1922.

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

The tendency toward the formation of secondary cyclones slightly to the south of the primaries and the large number of barometric troughs in evidence during the month were characteristic features.

The influence of oceanic pressures on both eastern and western borders of the continent was also well marked and the movement of anticyclones southeastward over New England as noted for March also continued during the first decade of the month.

Pressure was everywhere above normal except over New Mexico and contiguous regions.

The temperature distribution was greatly like that of the previous month—warm to the eastward of the Rocky Mountains, cool to the westward.

There was more than the usual amount of rain from Texas northeastward to the Great Lakes, also over the northeastern Rocky Mountain slope. It was drier than usual in Atlantic Coast States and in the southern portion of the Gulf States, also in California, Nevada, and Idaho. The usual details follow.

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

Most of the important cyclones of the month originated as secondaries over the Southwestern States, and during the first half of the month were confined to a relatively narrow track extending from this region toward the northeast. During the third decade anticyclonic areas occupied the North Central States, and the movement of cyclones became most erratic.

The anticyclones were generally offshoots from the North Pacific anticyclone.

Tables showing the number of cyclones and anticyclones by types follow:

LOWS.	Al- berta.	North Pa- cific.	South Pa- cific.	North- ern Rocky Moun- tain.	Colo- rado.	Texas.	East Gulf.	South At- lantic.	Central.	Total.
April, 1922.....	5.0	1.0	.....	.....	5.0	3.0	.....	1.0	.....	15.0
Average number, 1892-1912, in- clusive.....	3.4	1.6	0.9	0.5	1.3	1.0	0.3	0.6	0.7	10.3

HIGHS.	North Pacific.	South Pacific.	Al- berta.	Plateau and Rocky Moun- tain region.	Hud- son Bay.	Total.
April, 1922.....	7.0	.....	2.0	.....	1.0	10.0
Average number, 1892-1912, in- clusive.....	1.6	1.6	3.1	1.0	0.6	7.9

FREE-AIR CONDITIONS.

By W. R. GREGG, Meteorologist.

Temperatures were slightly above the average at all altitudes and at all stations except near the surface at Due West, S. C.¹ In general, the departures were somewhat greater above than below 1 kilometer; they were practically the same at all stations and for the most

¹ For the first time it is possible to compare current with normal values at this station. This comparison must, however, be made with the reservation that the station has been in existence only one year as against three to six years for the other stations. It must be further borne in mind that these are not true "normals" for which, of course, additional years' observations are necessary. They are nevertheless fairly close approximations.

part between 1° and 2° C. Reference to Climatological Chart IV will show a similar evenness of departure at the surface over all sections of the country east of the Rockies. Farther west there was a negative departure, most pronounced, though not excessive, in Utah and Nevada. At no time during the month were free-air temperatures remarkably high or remarkably low. The coldest period was from the 17th to 19th at Ellendale and Drexel, and from one to two days later at stations farther east and south. Even in this period the departures did not exceed 10° C. and for the most part were about 5° C. Positive departures of about the same amount were recorded generally about the middle of the month, particularly on the 16th.

Relative humidities were slightly above normal in the lower levels; at greater heights the departure was positive in the Southern but negative in the Northern States.

In conformity with the positive temperature departure vapor pressures were in generally somewhat higher than normal.

Resultant winds (Table 2) did not differ greatly from normal except near the surface at Ellendale, where an east component prevailed as against the usual west component. In the higher levels at this station, moreover, and at all altitudes above the other stations except Broken Arrow, the winds were somewhat more southerly than normal. This fits in well with the observed positive temperature departure.

Unusually high winds, 30 m. p. s. or more, were observed as follows:

[By means of kites.]

Station.	Date.	Dirac- tion.	Velocity.	Altitude.
Groesbeck, Tex.....	8	s.....	m. p. s. 31	Meters. 1,500

[By means of pilot balloons.]

Aberdeen, Md.....	15	wnw.....	32	2,700
Do.....	21	wnw.....	40	5,900
Do.....	24	n.....	33	4,700
Do.....	29	w.....	42	10,400
Broken Arrow, Okla.....	1	w.....	30	5,800
Do.....	14	nw.....	32	3,500
Do.....	18	wsn.....	39	4,400
Do.....	20	wnw.....	54	9,000
Do.....	21	wnw.....	42	9,100
Burlington, Vt.....	3	nw.....	34	6,800
Do.....	5	nwn.....	34	5,700
Camp Benning, Ga.....	20	w.....	30	5,200
Carlstrom Field, Fla.....	3	w.....	30	15,000
Do.....	24	ne.....	38	2,100
Due West, S. C.....	11	wsn.....	39	1,700
Do.....	20	w.....	30	5,300
Fort Sill, Okla.....	11	wnw.....	31	3,300
Groesbeck, Tex.....	8	wsn.....	32	1,300
Do.....	11	w.....	30	5,300
Do.....	19	w.....	31	6,000
Hampton, Va.....	11	sw.....	45	1,500
Do.....	20	wnw.....	30	2,500
Do.....	24	nwn.....	33	4,000
Langley Field, Va.....	11	sw.....	33	1,000
Lansing, Mich.....	9	sw.....	36	1,000
Do.....	15	nw.....	38	4,400
Do.....	17	w.....	30	1,900
Lee Hall, Va.....	1	wnw.....	30	3,100
Do.....	12	w.....	30	3,700
Madison, Wis.....	16	s.....	34	600
Mather Field, Calif.....	1	n.....	32	4,100
Do.....	11	nw.....	30	5,000
Do.....	16	nw.....	36	3,400
Do.....	17	n.....	30	4,800
Rockwell Field, Calif.....	13	wnw.....	34	3,700
Ross Field, Calif.....	9	nwn.....	39	3,900
Do.....	15	nw.....	35	5,000
Royal Center, Ind.....	12	wnw.....	34	3,000
San Diego, Calif.....	16	nw.....	33	3,000
Washington, D. C.....	2	nwn.....	37	2,800
Do.....	11	sw.....	32	1,500
Do.....	15	nw.....	36	1,700
Do.....	20	wnw.....	35	2,800

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

PRESSURE AND WINDS.

As has been the case during several months past, the atmospheric circulation during April, 1922, continued active, and cyclonic storms, particularly during the first two decades, moved eastward in rapid succession, principally from the southwestern districts.

Many of the cyclones did not reach wide proportions or extend as important storms into the more eastern districts; however, over the central and southern Great Plains and in the Ohio and middle Mississippi Valleys they gave copious precipitation on a number of dates.

The more important cyclones of the month occurred during the following periods: A storm central over the lower Ohio Valley at 8 a. m., March 31, had moved to the middle Atlantic coast by the morning of April 1, attended by moderate to heavy precipitation over nearly all districts from the Mississippi River eastward, with heavy snow in the northern portions of New York and New England, the depth at some points reaching 15 inches or more. The weather was mainly unsettled with low pressure and local rains over the interior and southwestern districts during the first week, and by the morning of the 8th a storm of considerable severity was central over the upper Mississippi Valley, with barometer readings as low as ever observed in April at points in Iowa and Missouri. This storm brought widespread rains over the central valleys, but lost energy after passing the Great Lakes, and moved to the eastward without material precipitation. This storm was quickly followed by a second one which likewise moved into the Great Lakes region, where it was central on the morning of the 11th, passing thence to the lower St. Lawrence Valley during the following two days. This storm likewise lost energy rapidly after passing over the Great Lakes, but high winds and low pressure marked its course over portions of the Great Plains, central valleys, and Great Lakes. Rains were general and frequently heavy from the Plains eastward, except over some southeastern districts, and more or less snow fell in the Rocky Mountains and adjacent regions. Disturbed conditions continued over the central valleys and most eastern districts until about the beginning of the last decade, when higher barometric pressure developed and more settled weather prevailed until near the end of the month, except for occasional local rains, particularly in the Southern Plains region, where about the 24th to 25th some phenomenal rains occurred, Fort Worth, Tex., reporting nearly 10 inches in less than 48 hours. The last few days of the month brought general rains over most districts from the Southern Plains eastward.

Anticyclonic areas were confined largely to the districts from the Great Lakes eastward during the greater part of the first two decades. By the end of the second decade, however, an anticyclone of considerable proportions had moved from the Pacific coast region to the lower Mississippi Valley, and during the remainder of the month pressure was relatively high over most southeastern districts.

The average pressure for the month was above normal, as during the preceding month, over practically all portions of the United States and Canada, the only exception being a small area from southern Texas northwestward into Colorado and portions of Kansas. Over the far Northwest the averages were well above normal and also above those of the preceding month.

From the Ohio Valley southeastward to the coast, average pressures were well above the normal and this condition probably extended into the adjacent ocean, as the monthly mean pressure at San Juan, Porto Rico, was the highest of record.

Due to high pressure over the southeastern districts, the prevailing winds over much of the region from the Great Plains eastward had a strong southerly component, while high pressure over the far Northwest induced winds from westerly points over large areas from the Rocky Mountains to the Pacific.

High winds occurred over extensive areas in Kansas, Missouri, and portions of adjoining States on the 8th, and generally over the same region, but extending eastward into the middle Mississippi and Ohio Valleys, and over portions of the Great Lakes and Middle Atlantic States on the 10th and 11th. Winds were also high in the upper Mississippi Valley, over the Great Lakes, and along the Atlantic coast from New York northward on the 18th to 20th. At points on the Great Lakes the winds on the 19th and 20th were the highest ever observed in April.

On the Pacific coast, at Point Reyes Light, Calif., an average wind velocity of nearly 33 miles per hour was maintained throughout the month, the highest average ever recorded for April.

A list of the more important storms of the month appears at the end of this section.

TEMPERATURE.

Important changes in temperature were confined mainly to the first two decades of the month, notably on the 11th and 12th, when they amounted to 20° or more in 24 hours over a large area from the Southern Plains to the Great Lakes, and on the 18th and 19th over considerable areas from the middle Mississippi Valley eastward.

The coldest periods of the month, covering extensive areas, were about the 1st and 2d over the Mississippi Valley, the upper Lakes and portions of New England, and the South Atlantic States; about the 15th to 18th in most districts from the Rocky Mountains westward; and about the 22d to 24th in portions of the Ohio Valley and Middle Atlantic States.

Minimum temperatures were below zero over the more elevated districts of the western mountains, and were locally more than 10° below in some of the northern Rocky Mountain States. They were below freezing in all districts save along the South Atlantic coast, over Florida, and the immediate Gulf coast region, at the lower elevations of Arizona and over the coast districts of the Pacific States.

The highest temperatures were observed during the first decade over most States from the middle Plains eastward, about the middle of the second decade in the Southern States from Texas and Oklahoma eastward, and during the last decade from the Rocky Mountains westward.

As a whole the month continued warmer than normal, as has been the case for several months, over most districts from the Great Plains eastward. On the other hand, it continued colder than normal over the more western districts, where temperatures decidedly below normal have been the rule for a number of months.

In portions of the Plateau region cold weather was almost continuous, and the averages for the month were among the lowest of record for April.

PRECIPITATION.

The distribution of the precipitation during April, 1922, is graphically shown on Chart IV of this REVIEW.

In general the month had decidedly more rainfall than is normally received in April over a large part of the central valleys and portions of the near Southwest. This was particularly true from central Texas northeastward to the lower Ohio Valley, where the monthly amounts ranged up to as much as 18 inches, and in portions of Kansas, Oklahoma, and nearby points, the precipitation was the greatest of record for April. Precipitation was also above normal in the Rocky Mountain and Plateau regions, and locally in the South Atlantic States.

It was less than normal in most Atlantic coast sections, along the East Gulf coast, over the Florida peninsula, and generally over California, Oregon, and portions of adjoining States. In central and southern Georgia and generally over Florida, the month was distinctly dry, no precipitation occurring during the entire month in portions of southern Florida, and no material rains occurring over large areas in those States.

SNOWFALL.

As may be expected in April, snow occurred over a wide extent of the country, but the amounts were usually

small save in the mountain districts of the West and from the Lake Superior region westward and southwestward to the Dakotas and Iowa and over the northern portions of New York and New England.

In the western mountains snow was heavy, the total falls ranging up to 4 feet or more at some of the higher elevations in Colorado, Wyoming, and adjacent States, and nearly as heavy falls were reported from many of the higher elevations of the Plateau region. In the Cascades heavy snows were reported from the higher elevations of Washington, with somewhat less in Oregon. In the Sierra of California the amounts were usually about the average for April.

RELATIVE HUMIDITY.

For the country as a whole, the relative humidity was distinctly above normal, only a few localities having averages appreciably less. Notable excesses were reported from the Rocky Mountain and Plateau regions, and they were only slightly less in the Ohio, Mississippi, and lower Missouri valleys. Important negative departures were observed in the Great Valley of California, and there were small areas having humidity averages for the month less than normal in the Appalachian Mountains, the Middle Atlantic States, and the Florida peninsula.

Severe local storms.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the chief of bureau.]

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
Currie, Tex.	3	11 A. m.				Wind and rain.	Several derricks wrecked, a theater and other buildings demolished. Loss estimated at thousands of dollars.	Times-Herald (Dallas, Tex.).
Pike County, Ala.	5					Tornado.	One person injured and a dwelling wrecked.	Official U. S. Weather Bureau.
Central Georgia.	5	P. m.				Wind, rain, hail.	Heavy crop loss and considerable property damaged.	Macon Telegraph (Macon, Ga.).
Indianapolis, Ind.	6					do.	Two persons injured and several thousand dollars damage to property.	Indianapolis News (Ind.).
Woodward, Iowa (near)	7			1	\$250,000	Tornado.	Several persons injured and property damage heavy.	Belvidere Republican (Ill.).
Council Bluffs, Iowa.	7				50,000	Hail.	Greenhouses, windows, autos, and street-car windows damaged.	Do.
Janesville, Wis.	7	A. m.				Electric and wind.	Property considerably damaged.	The Capital Times (Madison, Wis.).
Northern Texas and southern Oklahoma.	8	A. m.		17		Tornadoes.	Property loss heavy. Wire communication badly crippled and scores of persons injured. Damage estimated at hundreds of thousands of dollars.	Dallas Morning News (Tex.), Wichita Eagle (Kans.).
Nodaway County, Mo.	8	P. m.				Wind.	Principal damage to wire systems and farm buildings.	Daily Democrat (Maryville, Mo.), St. Joseph New-Press Mo.
Murphysboro, Ill.	8	P. m.				do.	Damage to barns and fences amounting to several thousand dollars.	Cairo Evening Citizen (Ill.).
Davenport, Iowa, and vicinity.	8-9					do.	Telephone and telegraph service crippled, glass broken, trees down, and minor property damage from high wind.	Official U. S. Weather Bureau. The Democrat (Davenport, Iowa). Rock Island Argus (Ill.).
Denver, Colo. (near)	9					Gale and snow.	Hundreds in autos marooned in roads suffer from severe cold.	The Post (Denver, Colo.).
Chicago, Ill.	9					Gale.	General damage done; several injured. Wind velocity, 48 miles.	Herald-Examiner (Chicago, Ill.). Official U. S. Weather Bureau.
Memphis, Tenn.	10					Wind.	Material damage to river craft, one building unroofed, and telegraph service out of use.	Chattanooga News (Tenn.).
Green, Clark, and Champaign Counties, Ohio.	10			1	100,000	Tornado.	Extensive property damage; 5 persons injured.	Ohio State Journal (Columbus, Ohio).
Eastern Colorado.	10					Wind and snow.	Railway and telephone service paralyzed.	The Pueblo Chieftain (Pueblo, Colo.).
Springfield, Mo. (12 miles northwest of).	10			2	100,000	Tornado.	Heavy property damage; many persons injured.	Official U. S. Weather Bureau.
Eastern Tennessee.	10-11					Wind.	Considerable minor damage.	Do.
Kansas, Oklahoma, Missouri, Texas.	10-11			2	400,000	Wind and flood.	Heavy general damage; 7 persons injured.	Official U. S. Weather Bureau. Evansville Press (Ind.).
Monroe, Wis.	11				100,000	Wind.	12 barns damaged and many farm buildings wrecked.	Evening News (Monroe, Wis.) Official U. S. Weather Bureau.
Augusta County, Va.	11					do.	Silo damaged and also other farm buildings.	Staunton News-Leader (Va.).
Middle Tennessee.	14	P. m.			300,000	do.	Destruction of wide extent. Many buildings wrecked, several persons injured, and stock killed.	Official U. S. Weather Bureau.
Belleville, Ill.	14	A. m.				do.	School demolished and thousands of dollars damage to dwellings.	Belvidere Republican (Ill.).

Severe local storms—Continued.

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
St. Louis, Mo., and vicinity..	14	A. m.			150,000	Wind, rain, hail...	Buildings, telephone, telegraph lines, and trees damaged.	Belvidere Republican (Ill.).
Louisville, Ga.	15					Wind.	Barns, fences, houses, and crops; also communication lines damaged.	Official U. S. Weather Bureau.
Central and eastern Ohio.	15-17			3		Wind and floods.	Storm leveled barns, sheds, and fences. Many families forced to leave homes. Wires down.	Plain Dealer (Cleveland, Ohio).
Iola, Kans., and vicinity.	16	P. m.			100,000	Wind, hail, and thunderstorm.	Damage to many industries.	Official U. S. Weather Bureau. Wichita Beacon (Kans.). Wichita Eagle (Kans.).
Crawford and Franklin Counties, Ark.	16	P. m.				Wind.	Severe damage to property and overhead wires.	Fort Smith Times Record (Ark.).
Central States.	16-20			30		Tornadoes and floods.	Several hundred persons injured and property and property damage running into millions. Illinois and Indiana hardest hit.	Illinois State Register. Evansville Courier (Ind.). Times (Toledo, Ohio). Brooklyn Eagle.
Iola, Kans. (west and north of).	17				20,000	Wind and rain.	All kinds of property damaged.	Official U. S. Weather Bureau.
Royal Center, Ind.	17					do.	Damage to buildings from winds and much flooding. Extent of damage not known.	Do.
Buffalo and lower Lakes regions.	19-20					Gales.	Minor damage to vessels and along water fronts, and also to buildings. 80-mile wind at Buffalo.	Official U. S. Weather Bureau. Journal (Milwaukee, Wis.). Commercial (Buffalo, N. Y.).
Groesbeck, Tex.	24	P. m.				Wind.	Considerable damage to trees, awnings, etc. Extreme velocity of wind, 84 miles.	Groesbeck Journal (Tex.). Official U. S. Weather Bureau.
Fort Worth, Tex.	25			11	600,000	Wind and floods.	1,500 homeless. Heavy property losses.	Journal of Commerce (Chicago, Ill.). Herald (Palestine, Tex.).

STORMS AND WEATHER WARNINGS.

By EDWARD H. BOWIE, Supervising Forecaster.

WASHINGTON FORECAST DISTRICT.

The morning of the opening day of the month a disturbance of considerable intensity had its center south of Cape Cod and was moving northeastward, attended by general snows and rains in the North Atlantic States, the Lower Lake region, and the upper Ohio Valley. Storm warnings were displayed the last day of the previous month and they were changed to warnings of northwest winds and gales the morning of the 1st at and between Delaware Breakwater and Nantucket, and on the 2d warnings were continued for the same region. This storm was accompanied by gales on the Middle Atlantic and New England coasts and it was followed by much colder weather in the Washington forecast district, frost and freezing temperature forecasts being required on the 2d and 3d, except on the South Atlantic and Gulf coasts. For a week following this disturbance the pressure continued high in the Eastern States, although showery weather occurred on a number of days.

In the Western States, however, the pressure remained low and there was a succession of disturbances over the west and southwest which moved northeastward. Among them the most important and at the same time interesting storm made its appearance over Mexico on the morning of the 7th and moving north-northeastward it crossed into Texas during the night of the 7th and moved thence rapidly to the region of the Great Lakes, where it was dissipated. This disturbance was attended by general rains over the area traversed by it, and it caused a number of severe local wind storms over the southern Plains States. While this disturbance was moving northeastward another was in the northwest, whence it moved southeastward and the morning of the 9th it was central over eastern Colorado. From Colorado it advanced east-northeastward and the disturbance gained greatly in intensity during the 10th. On the morning of the 11th its center was over Lake Michigan and gales had become general in the great central valleys and the region of the Great Lakes with widespread precipitation.

At the time when this disturbance was central over the Great Lakes, southwest storm warnings were ordered displayed on the Atlantic coast at and north of Cape Hatteras, and strong shifting winds and gales were more or less general along this stretch of the coast. The pressure remained low in the southwest during the 11th to 14th, and made necessary the issue of forecasts of precipitation for considerable areas of this forecast district. On the 14th another disturbance appeared in the far northwest, moved southeastward to the central Rocky Mountain region, and thence passed northeastward and reached the St. Lawrence Valley on the 18th. While in the far West this disturbance caused snows in the Rocky Mountain region and later it was attended by general precipitation in the Great Central valleys and the Eastern and Southern States. On the morning of the 17th when the center of this disturbance was over the Great Lakes, southwest storm warnings were ordered displayed on the Atlantic coast at and north of Cape Henry, and on the morning of the 18th these warnings were continued displayed. Following this disturbance the temperature fell decidedly, and frost warnings were issued the morning of the 18th for the lower Lakes region, the Ohio Valley, Tennessee, and the mountain districts of the Middle Atlantic States.

On the 19th, when a disturbance was central over the Great Lakes, southwest storm warnings were displayed on the Atlantic coast at and north of Sandy Hook. This disturbance passed down the St. Lawrence Valley during the night of the 19th and it was followed by strong westerly winds and gales on the north Atlantic coast, the highest velocity reached being 72 miles an hour at New York City. From the 19th to the end of the month the pressure remained high and the weather generally cold for the season in the Eastern and Southeastern States and forecasts of frosts were required on a number of days for the Ohio Valley, the lower Lake region, and the Atlantic States as far south as the Carolinas. The frosts were severe in the Middle Atlantic States and the upper Ohio Valley, where vegetation was sufficiently advanced to be injured.

Northwest storm warnings were ordered on the 27th for the Atlantic coast at and north of Delaware Break-

water. Advisory warnings of winds of force sufficient to interfere with navigation on Lake Michigan were issued on the 5th, 8th, 9th, 10th, and 11th. After the 15th the storm warnings for the Great Lakes were issued from the district forecast center at Chicago.

CHICAGO FORECAST DISTRICT.

The limits of the Chicago Forecast District were much enlarged during the month of April, 1922. For many years the district comprised the following States: Illinois, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Nebraska, North and South Dakota, Montana, and Wyoming. On the 16th of April the States of Michigan and Indiana were added, as well as the storm-warning service for the Great Lakes and flying forecasts for zones 4, 7, 8, and 10, these zones embracing the area covered by the forecast district and the Great Lakes. These additions to the Chicago Forecast District were through transfer from the Washington District.

The month of April was marked by frequent storm movement across the district, so that the precipitation over most of the region was considerably above the normal, and excessive even at several points in the central valleys. At the opening of the month flood stages had already developed along the Illinois River, and these conditions became more aggravated from the frequent rains during the month of April, and gradually extended to the section of the Mississippi in the vicinity of the confluence of the Illinois with that river. The task of forecasting river and flood stages is in the hands of the local forecasters, under the direction of the River and Flood Division at Washington, and reference to this portion of the work of the Bureau is made elsewhere in this publication. (See pp. 216.)

April 16 was the date fixed for the beginning of the storm-warning season on the Great Lakes, coincident with the time of the transfer of that service from Washington to the Chicago Forecast District. Immediately thereafter two storms in quick succession moved across the Great Lakes with increasing intensity, one on the 17th and the other on the 19th and 20th. The first of these disturbances was attended by fresh to strong winds reaching gale force on the Lower Lakes with thunder squalls of considerable intensity. The second disturbance was more general, the wind reaching gale force over a wide area. Unusual velocities were attained at several stations, but no damage to shipping was reported, in spite of the fact that early warnings were not possible on account of the sudden and rather freakish development of the storm. The lack of casualties was chiefly due to the fact that a comparatively small number of ships were in commission at the time of the storms.

On the 8th and 9th a rather unusual storm for the season of the year developed in the Rocky Mountain region, pushing southeastward to Montana and Kansas; considerable snow with strong winds and freezing temperature followed in the northern and central Rocky Mountain region and adjoining sections. Live-stock warnings were sent to points in Montana, Wyoming, and the Dakotas on the morning of the 8th, and these doubtless resulted in preventing great loss to stock.

With the advance of vegetation, warnings of the occurrence of frosts became necessary, gradually reaching northward over all the district by the end of the month, except in the more northerly and westerly sections.

During the second half of the month frost occurred a few times in the eastern, southern, and central portions

of the forecast district, and warnings were in practically every case sent in advance to the threatened sections.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

Small-craft warnings were displayed on the Texas coast April 2, 3, 7, 10, and 16 and were justified. Southeast storm warnings were ordered for the Texas coast April 4, 7, and 8, and storm-verifying velocities as a rule occurred generally during these displays. No general storm occurred without warning.

Frost occurred in the northwestern portion of the district on the 11th and in the northern portion on the 18th and 19th, for which warnings were issued.

Norther warnings were issued for Tampico April 19.—*I. M. Cline.*

DENVER FORECAST DISTRICT.

The month was abnormally cold in the Denver Forecast District, retarding the development of fruit buds.

On the morning of the 8th an area of low pressure was central in the northern Rocky Mountain region. It moved southeastward across the district, attended by freezing temperatures in western Utah on the 9th, Modena, Utah, reporting a temperature of 8°. Freezing temperatures prevailed on the morning of the 10th, except in the extreme southern portion of the district, with readings of 18° at Durango and Santa Fe, and on the morning of the 11th freezing temperatures were reported as far south as the Pecos Valley, with a heavy frost at Roswell. Timely warnings were issued for these conditions. A disturbance, that was over Colorado on the morning of the 15th, moved southward to northern New Mexico on the 16th, and was followed by an anticyclonic area that overspread the entire district by the 18th. Freezing temperature or frost warnings were issued for the greater part of the district on the 15th, 16th, 17th, and 18th, and included southeastern New Mexico on the 17th and 18th. Freezing temperatures occurred as forecast, with readings of 15° to 20° in the fruit valleys of Colorado on the 18th and 24° to 28°, with heavy frost in the Pecos Valley on the morning of the 19th. Another area of high pressure occupied the northeastern slope on the morning of the 27th and the barometer was rising in most western districts. Warnings of frost or freezing temperature were issued for western Colorado and frost in northern and eastern New Mexico. While cold weather, with freezing temperatures, occurred in localities in the Gunnison Valley, in western Colorado, a trough of low pressure developed on the western slope and the attending cloudiness prevented the formation of frost.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

The weather during the first half of the month was much like that of March, when a succession of small depressions moved inland over British Columbia and thence southeastward over the Plateau. This condition gave many days of precipitation, but the amounts were small, over the northern portion of this district. The precipitation seldom extended south of Cape Mendocino on the coast and southern and eastern Nevada in the interior. In California only a few light showers fell. The latter part of the month was marked by a change to fair weather which was unbroken except for rain in Washington and Oregon on the 22d and western Washington on the 27th and 28th.

The cause producing this sudden transition from a wet to a dry condition is undoubtedly the position of the Pacific HIGH. During the wet period it was central near the middle of the ocean, but about the 17th it moved much nearer the coast and this movement was followed by the dry weather. It is further believed that the proximity of the high to the coast is more controlling than the latitudinal position, although the latter is also an important factor in producing this weather sequence.

Storm warnings were issued five times during the month, as follows: Washington and Oregon coast on the 7th and 13th and on the California coast on the 4th, 8th, and 11th. The warnings were generally verified.

Frost warnings were issued in northern California on the 8th, 9th, 15th, 16th, and 17th and in Washington and Oregon on the 15th, 16th, 17th, 23d, 24th, and 25th, and were all timely.

Live-stock warnings were issued in eastern Washington, eastern Oregon, and Idaho on the 22d. This warning was only partly successful; the expected fall in temperature occurred, but instead of rain or snow the weather was clear.—G. H. Willson.

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

Reference to the flood table at the end of this report will disclose the wide distribution of floods during the month of April. Virtually every stream east of the Rocky Mountains, except those in the Northwest, was in flood at some time during the month. The great floods in the Mississippi and its larger tributaries were at their height, but there were also other destructive floods of a more local character, notably in the upper Trinity River of Texas.

As the Mississippi flood was still in progress at the close of the month, report thereon will be delayed until after its final subsidence over the lower reaches, which will be sometime during the first half of June. A somewhat elaborate special report of this flood is contemplated, but its appearance will be delayed for several months. However, a summary thereof will appear in the MONTHLY WEATHER REVIEW for June, 1922, and mention may be made here that the flood from the mouth of the Arkansas River to the Passes was the greatest in history, and only the failure of portions of the levee system prevented still higher stages from Vicksburg, Miss., southward to the Gulf of Mexico.

Omitting further reference to the floods in the Mississippi drainage basin, those over other areas will be taken up in order, beginning with the Atlantic Basin.

Connecticut River.—In magnitude this flood is the 15th within the history of authentic flood records at Hartford, extending back to 1841 and probably to 1801. Prior to 1870 no systematic attempt had been made at this point to measure the daily water stage. Before that time the highest water of the floods was permanently marked by driving iron spikes into a wooden building (a brewery) that stood near the river's edge, so when the Army engineers began surveying the river in the early seventies they established a gage here and by careful leveling referred these flood crest marks to the present gage. It is believed that this record at Hartford of flood heights and continuity is not exceeded elsewhere in the United States, covering, as it does, the annual crest wave since 1838 and dates of the opening of the river since 1817.

On January 9, 1841, there was a crest of 26.3 feet, with a note, "the highest flood since 1801, and destroyed

many bridges over the river in the upper valley. The Hartford bridge was much damaged."

1801, March 20, 27.5 feet, with note, "no mark so high since 1692. It was the result of a three-day heavy rain, causing streams to rise rapidly to unexampled height, and resulting in an immediate inundation, loss of life and destruction of property."

1692. February 23, 26.2 feet. (Massachusetts Historical Society Proceedings.) Diary of Capt. Lawrence Hammond of Charlestown and Boston. "Feb. 23, 1692. Rain in ye nite & Continued all ye week, more or less to rain wth much wind betw ye S. E. & N. E. 28th. Likewise much rain and wind, som raine ye 29 also. March 1, Wind at NW & cleare weather. These rains wth ye Violent sudden melting of ye snow in ye Wilderness caused such a sudden & Violent flood yt hath done abundance of damage in most parts of ye country, carrying away bridges, Mills, & c. Connecticut River higher yn ever it was known before, destroyed much cattel in ye meadows, carryed away some Houses & washed away in many places ye very land with ye English graine sown in it."

History of Northampton, Mass. "Flood February 1692 was the highest experienced in this section of the valley previous to 1801. Medad Pomeroy's account of it represents the rain as falling for 5 days almost continuously, during which time the sun was not seen and the water rose to such a height as was scarce known in the country before. Much damage done throughout this entire region."

1683. July-August, flood, 26.0 feet.

1639. March 19, great flood. This is the earliest flood of which we have record. (Mass. Col. 4th series, vol. 6, page 355.) Letter from John Haynes to John Winthrop, dated Wethersfield, 27th, 1st. month, 1639 (i. e. March 27): "Wee have lately hadd a great floode that came upp to some of our houwses and carryed away a good parte of our fences in our lowe grounds. Otherwise wee blesse the Lord, wee are generally in good health." Matthew Grant, Windsor Church records, original mss. at Conn. His. Soc. Hartford, "I found in the old book that the great flood began the 5th. of March 1638/9. On the 11th. day of March it began to fall, but by reason of much rain on the 12th. day, it rose very high. On the 14th. two youths were drowned being in a canoe on the flood gathering up pales swimming on the flood against Thomas Dewey's house. Matthew Ramond and Henry Lush. On the 15th and 16th days it (the flood) had fallen near two feet, but on the 16th day was much rain and great wind out of the southeast which made it exceeding great storm. It indamaged houses and break down many trees so that by the cause of which rain all the 17h and 18th days the water rose very high, more than had ever before been known by the Indians. It drowned many houses very deep and indamaged many cattle over (i. e. east of) The (Great) River, for all the ground there was drowned to one little ridge where Samuel Grant now lives. (This was in the present town of South Windsor just in rear of the Theological Seminary.) It carried away much timber and hay and beat up pales out of the ground, and post and rails, and carried them away and whole trees and all. On the 18th day at night there was a great fear of another storm of wind and rain. It began but it pleased the Lord, it ceased quickly, and by the morning one might perceive the water was begun to fall, and so it continued. On the 22nd day at night it was well fallen, and yet it was as high as the highest flood we had known before."

For the flood of 1922 warnings were issued from April 8 to 12, inclusive. The flood stage of 13 feet at White River Junction, Vt., was passed on the 8th, and on the morning of the 13th a crest stage of 26.8 feet was reached. A stage of 24 feet, 8 feet above flood stage was forecast for Hartford, where the river had remained in moderate flood since March 29, and later increased to 24.5 feet for April 14. The crest was 24.5 feet on the day specified. At Holyoke, Mass., the crest stage on April 13 was 11.35 feet, 2.35 feet above flood stage.

The winter was devoid of the usual "thaws," so that the snow remaining in the north mountains and sheltered places was in a condition to melt rapidly with the rain and high temperature. On the 10th there was a temporary cessation as the White River emptied at our outpost, White River Junction, but during the next 24 hours there was another rapid rise, and, swollen that night by a heavy rain which concentrated generally over the central portions of Vermont and New Hampshire, all streams were soon transformed into raging torrents. The Passumpsic and the Wells particularly, being short steep streams, emptied volumes of water into the main stream, which by this time had become very high, due to the overflowing of the Connecticut lakes. The combined result was that the swollen waters of the upper Connecticut rose to a record surpassed but once since the Weather Bureau began its river work in this valley.

From the source to the mouth of the river much damage was inflicted to dwellings and other buildings. All along the valley crews of men worked night and day to ward off more serious consequence. Happily there was an absence of ice with the flood, and fortunately very few log drives were in the river this winter, so the chance for loss by these was small. However, large quantities of wood, poles, ties, beams, etc., piled near the river disappeared, and in addition the floating debris consisted of portions of buildings, garages, hencoops, uprooted trees, etc. Families living in the meadows moved to upper stories of the houses, having egress and ingress entirely by boat. Others were forced to abandon their homes entirely during the high water. This was especially the case in the river sections of the cities. Stores and shops in the lower business sections of the cities were flooded and activities abandoned, and many fields that had been prepared for planting were covered with several feet of water. In cases, no doubt, the farmer found that his fields were well fertilized by the oozy mud left by the receding waters, while in many others they found that where once were rich loamy fields there now are gullies, expensive to reclaim. Railroad beds and tracks were washed out, while on the tributaries bridges were washed away and highways cut out as though built of sand, leaving the water running through deep gullies.

Railroad transportation was seriously handicapped, and regular schedules were abandoned, particularly on the Central Vermont, and many divisions of the Boston and Maine Railway. Tracks were undermined and torn away, culverts and bridge abutments washed away, while landslides were reported near Ryegate, McIndoes, and Wilder, Vt.

There were two serious train derailments, one killing three trainmen, and at Hartford one young girl was drowned. Industrial plants in many cities and towns were closed, and no steamer landings could be made between Hartford and the mouth of the river.

No reliable estimate of the amount of loss and damage could be obtained but it undoubtedly ran into hundreds of thousands of dollars, if not a million.—*Abstracted from*

the report by Mr. W. W. Neifert, meteorologist in charge, Weather Bureau Office, Hartford, Conn.

Hudson River.—This flood was due to the same general conditions that prevailed over the Connecticut Valley, and warnings were first issued on April 11. A stage of 17 feet, or 5 feet above flood stage, was forecast for Albany, N. Y., on April 12 and the crest stage from 9 to 12 p. m. on that date was 16.8 feet.

The accuracy of the warnings occasioned much favorable comment, and the losses did not exceed \$50,000. The value of property saved through the warnings was between \$25,000 and \$35,000.

There were no other floods of consequence in the North Atlantic States.

The floods in the Peedee and Santee systems were moderate, although flood stages were generally exceeded by from 2 to 6 feet. The Santee River remained in flood throughout the month and had been in that condition since the early days of February, 1922.

Losses and damage reported amounted to \$12,000 or \$13,000, largely to hogs and growing oats, while the money value of property saved through the warnings issued was reported at \$90,000.

The flood in the Apalachicola River of Florida was moderate and featureless.

East Gulf Drainage.—There were two floods in the Tombigbee basin of Alabama. While neither was of great importance, yet the warnings issued were of considerable value to farming and lumber interests. The losses and damage so far as reported amounted to \$10,300 and the value of property saved through the Weather Bureau warnings to \$20,800.

Floods continued from March over the lower Pearl River system of Mississippi and Louisiana, but, as the season was early, no great damage was done. Warnings were issued as often as necessary, and the total losses did not exceed \$8,500, while the value of property reported saved by the flood warnings was \$11,000.

Great Lakes Drainage.—There were two moderate floods in the Maumee Basin of Indiana and Ohio. The first was caused by the heavy rains of March 30, and the flood stages were exceeded during the early days of April with a maximum crest of 19.4 feet, 4.4 feet above flood stage, at Fort Wayne, Ind., on April 1. Additional substantial rains from April 10 to 18, inclusive, were responsible for the second flood which lasted from April 12 to 22, inclusive, with a crest stage at Fort Wayne of 17.7 feet on April 15 and 16. Warnings were issued in ample time and there was no damage of consequence. The floods in the Sandusky River of Ohio, and the Saginaw and Grand River systems of Michigan were very moderate and the damage slight.

North Canadian River.—There were moderate to heavy rains on April 8 and again from April 24 to 30, inclusive, over the North Canadian basin, and high water resulted from Oklahoma County, Okla., eastward to the junction with the Canadian River. Low bottom lands were submerged, but there was little or no damage, as the warnings which were disseminated through the cooperation of the Oklahoma State board of agriculture enabled farmers and others to remove and protect property.

Rivers of Texas.—All rivers of Texas, except the Rio Grande, were in flood at some time during the month. There were two floods in the upper Trinity, the Brazos, Neches, Colorado, and Guadalupe Rivers, one in the lower Sabine, and one continuous flood in the upper Sabine and lower Trinity Rivers, that began in March and continued into May, 1922.

The Sabine and Neches floods were severe, and at the time of the flood crest the Neches River was $1\frac{1}{2}$ miles wide, and on the left banks of both the Sabine and Neches Rivers the overflow waters ran from 1 to 3 feet deep over a width of 3 to 6 miles. At Logansport, La., on the Sabine River, the crest stage of 34.7 feet on April 2 was 9.7 feet above the flood stage, while at Rockland, Tex., on the Neches River, the crest stage of 28.9 feet or 8.9 feet above the flood stage, on the same date was the highest stage of record.

The losses reported along the two rivers amounted to \$126,000, while property to the money value of \$50,500 was reported as having been saved through the warnings.

The first flood in the upper Trinity River was caused by abnormally heavy local rains on April 2 to 4, inclusive. At Dallas, Tex., 6.08 inches fell in 24 hours, and at Fort Worth, Tex., 5.33 inches. Flood stages were not reached above Dallas, but at Dallas the crest stage was 36.5 feet on April 5, and at Trinidad, 38.3 feet on April 11, flood stages being at 25 and 28 feet respectively.

These crest stages closely correspond with the forecast stages, and the warnings issued on April 3 and 4 permitted the saving of property of an aggregate value of \$55,000. The losses, mainly to roads and bridges, amounted to about the same.

The second flood, which occurred throughout the entire length of the Trinity River, was due to still heavier rains from April 24 to 26, inclusive.¹ At Fort Worth 7.55 inches of rain fell during the 24 hours ending at 7 a. m., April 25, and 3.06 inches during the following 24 hours, a total of 10.61 inches in 48 hours, while at Weatherford, in the adjoining county to the westward, the figures for the corresponding periods were 6.75, 4.30, and 11.05 inches, respectively. Below Fort Worth the rainfall was not so heavy, although Dallas reported 5.36 inches in the two days.

The crest stage of 39.1 feet, or 9.1 feet above flood stage, at Fort Worth on April 25 was the highest stage of record and 1.5 feet above the previous high stage of June 10, 1915. The crest stage of 42.3 feet at Dallas on April 27, although 17.2 feet above flood stage, was 10.3 feet below the record stage of May 25, 1908. Correspondingly high stages were experienced below Dallas, and only the local character of the torrential rains prevented a general flood beyond all previous records.

This flood was also forecast with the usual accuracy and the warnings were highly commended on all sides. Local authorities, especially in Dallas, assisted in the widespread distribution of warnings, literally from house to house in some sections, and many lives and much property were saved thereby. Unfortunately, 11 lives were lost in the vicinity of Fort Worth, the victims being caught by the sudden rush of water, and a number of person were reported missing.

The general damage was of the character incident to great sudden overflows, and in addition a number of levees were broken and two dams were washed out. From below Bridgeport southward the river ranged from 1 to 7 miles wide at the peak of the flood, and hundreds of square miles of land were submerged. The losses and damage amounted to more than \$1,000,000, of which only \$6,700 (\$5,000 at Fort Worth) was in live stock. As there were more than \$1,000,000 worth of cattle in the lowlands prior to the flood, the loss of less than 1 per cent affords another illustration of the efficiency of the flood-warning service. It has been difficult to obtain estimates of other property saved by the warnings, although a few

persons reported an aggregate of \$132,725. There was certainly much more.

Some additional details of the local flood at Fort Worth may be found in another portion of this REVIEW. (See pp. 188-189.)

The first flood in the Brazos River began at Waco on April 4 with a 24-hour rise in the river of 18.7 feet to a stage of 25.5 feet, 1.7 feet below the flood stage. The crest of 33.3 feet occurred at 8 p. m. of the same day. The width of the river was then about 1 mile, and 50,000 acres of land in McLennan County were under water. At Washington the crest stage of 49.9 feet, 4.9 feet above the flood stage, occurred at 1 p. m., April 8, when the river was 2 miles wide. The crest reached the mouth of the river at Freeport on April 13, with a stage of 42 feet, 0.2 foot above the flood stage.

The second flood began with an initial rise of 18 feet in 24 hours at Kopperl on April 26, and the crest stage was 20 feet, 1 foot below the flood stage at 3:15 p. m. of the same date. At Valley Junction the crest stage on April 29 was 3.3 feet above the flood stage of 44 feet, and at the close of the month the water was flooding the lowlands around Washington with a river stage of 46.2 feet, 1.2 feet above the flood stage.

Although warnings were timely and frequent, the losses as reported amounted to \$821,500, mainly to growing cotton and corn, while property to the value of \$322,000 was saved through the warnings.

There were also two floods in the Colorado and Guadalupe Rivers, the first from April 5 to 7, inclusive, and the second near the close of the month. Flood stages were not reached during the first flood, except from Columbus southward, and only local warnings were issued. The second flood was a more general one, and flood stages were exceeded at all places below Ballinger. Warnings were issued at the proper time.

The early flood in the Guadalupe River reached serious proportions and did considerable damage to growing crops, etc. The Cuero Light & Power Plant was damaged to the extent of \$15,000, but no other figures are available. The crest stage of 23.9 feet at Victoria on the 9th was 7.3 feet above the flood stage and within 1.2 feet of the record flood of October 21, 1919. At Gonzales the river rose 28.5 feet in 24 hours on April 4-5 to a crest of 33.3 feet, 11.3 feet above the flood stage, and cattle to the value of \$5,000 were saved through the timely warnings at this place alone. The flood at the end of the month was less pronounced and was also well forecast.

Flood stages during April, 1922.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Connecticut:	Feet.			Feet.	
White River Junction, Vt.	13	(1)	1	13.4	
	13	9	22	26.8	13
Bellows Falls, Vt.	12	12	13	16.4	13
Holyoke, Mass.	9	12	16	11.4	13
	16	(1)	2	19.3	
Hartford, Conn.	16	10	22	24.5	14
Hudson:					
Corinth, N. Y.	10	12	13	11.1	13
Albany, N. Y.	12	12	16	16.8	12
Susquehanna:					
Oneonta, N. Y.	12	13	13	12.8	13
Pedee:					
Cheraw, S. C.	27	8	8	30.3	
Lynches:					
Effingham, S. C.	14	13	13	14.5	13
Santee:					
Rimini, S. C.	12	(1)	(2)	18.4	11
Ferguson, S. C.	12	(1)	(2)	14.3	12
Catawba-Wataree:					
Catawba, S. C.	12	7	7	15.0	
Camden, S. C.	24	7	9	29.3	

¹ Cf. Landis, D. S.: Rainfall and flood at Fort Worth, Tex. This REVIEW, pp. 188-189.

Flood stages during April, 1922—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.		River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.			From—	To—	Stage.	Date.
ATLANTIC DRAINAGE—continued.						MISSISSIPPI DRAINAGE—continued.					
<i>Broad:</i>	<i>Feet.</i>			<i>Feet.</i>		<i>West Fork of White:</i>	<i>Feet.</i>			<i>Feet.</i>	
Blairs, S. C.	15	7	8	19.7	7		12	1	1	12.2	1
<i>Saluda:</i>							12	11	12	12.8	11
Pelzer, S. C.	7	6	7	8.0	6-7	Anderson, Ind.	12	15	16	17.5	15
Chappells, S. C.	14	6	9	18.8	8		12	18	19	14.7	18
	14	20	21	16.0	20		14	12	12	14.7	12
<i>Congaree:</i>						Noblesville, Ind.	14	15	16	17.3	16
Columbia, S. C.	15	7	8	18.5	7		14	18	19	15.4	18
<i>Apalachicola:</i>						Elliston, Ind.	19	(1)	5	24.5	3
River Junction, Fla.	12	(1)	7	14.0	3		19	(1)	9	27.0	20
Blountstown, Fla.	15	(1)	11	17.0	3	<i>Mississippi:</i>					
<i>Tombigbee:</i>						La Crosse, Wis.	12	12	21	13.7	17
Lock 4, Demopolis, Ala.	39	3	10	46.7	6	Prairie du Chien, Wis.	18	17	22	19.4	19
	39	22	27	44.4	25	Dubuque, Iowa	18	17	26	21.0	20-21
<i>Black Warrior:</i>						Clinton, Iowa	16	18	29	19.0	22-23
Lock 10, Tuscaloosa, Ala.	46	20	20	48.5	20	Le Claire, Iowa	10	17	(2)	12.9	23
<i>Pearl:</i>						Davenport, Iowa	15	19	28	17.1	23
Edinburg, Miss.	21	2	4	22.0	3-4	Muscataine, Iowa	16	19	29	19.5	24
Jackson, Miss.	20	(1)	14	27.6	6	Keokuk, Iowa	14	15	(2)	17.6	23
Columbia, Miss.	18	3	10	20.2	5-6	Warsaw, Ill.	17	15	(2)	20.2	24
<i>West Pearl:</i>						Quincy, Ill.	14	14	(2)	18.7	25
Pearl River, La.	13	(1)	22	15.2	1	Hannibal, Mo.	13	12	(2)	18.9	25
						Louisiana, Mo.	12	10	(2)	17.0	26-27
GREAT LAKES DRAINAGE.						Grafton, Ill.	18	(1)	4	19.4	2
<i>Sandusky:</i>						Alton, Ill.	18	7	(2)	25.8	20
Upper Sandusky, Ohio.	13	18	18	13.5	18	St. Louis, Mo.	21	(1)	(2)	31.5	19-20
<i>Maumee:</i>							30	10	23	34.0	19
Fort Wayne, Ind.	15	(1)	5	19.4	1	Chester, Ill.	27	3	3	27.0	3
Napoleon, Ohio.	10	2	2	10.6	2		27	9	(2)	34.0	20-21
<i>St. Joseph:</i>						Cape Girardeau, Mo.	30	(1)	(2)	38.0	21-22
Montpelier, Ohio.	10	(1)	3	12.8	1	New Madrid, Mo.	34	(1)	(2)	41.7	20-22
	10	12	20	12.3	12	Memphis, Tenn.	35	(1)	(2)	42.6	1
<i>Casa:</i>						Helena, Ark.	42	(1)	(2)	52.9	30
Vassar, Mich.	14	12	13	14.7	12	Arkansas City, Ark.	45	(1)	(2)	58.0	22-27
	14	18	19	14.7	18	Greenville, Miss.	42	(1)	(2)	52.1	25-27
<i>Grand:</i>						Vicksburg, Miss.	45	(1)	(2)	55.0	28-29
Eaton Rapids, Mich.	5	1	5	5.2	3	Natchez, Miss.	46	(1)	(2)	55.5	26
East Lansing, Mich.	5	11	26	5.4	13	Baton Rouge, La.	35	2	(2)	44.6	27-28
Grand Ledge, Mich.	7	3	7	7.2	5	Donaldsonville, La.	28	(1)	(2)	35.8	27-28
	7	14	20	7.3	15, 19	New Orleans, La.	18	(1)	(2)	22.7	24
<i>Red Cedar:</i>						Wisconsin:					
Williamston, Mich.	10	13	13	10.0	13	Merrill, Wis.	11	11	11	11.0	11
MISSISSIPPI DRAINAGE.						Knowlton, Wis.	12	5	13	18.6	11
<i>Ohio:</i>						Wisconsin Rapids, Wis.	12	11	12	13.5	11
Cloverport, Ky.	40	21	22	40.1	21-22	Portage, Wis.	14	11	17	15.8	14
Evansville, Ind.	35	5	10	36.6	7	Illinois:					
	35	20	26	37.6	23	Morris, Ill.	13	(1)	22	20.1	12
Henderson, Ky.	33	5	10	34.7	8	Peru, Ill.	14	(1)	(2)	23.8	13
	33	20	26	35.9	23	Henry, Ill.	7	(1)	(2)	18.0	15-16
Dam No. 48, Ind.	42	6	9	42.7	8	Peoria, Ill.	16	(1)	(2)	24.8	15
	42	21	26	44.1	24	Havana, Ill.	14	(1)	(2)	22.6	20
Mount Vernon, Ind.	35	5	12	37.5	9	Beardstown, Ill.	12	(1)	(2)	25.1	20
Shawneetown, Ill.	35	19	28	39.5	24	Pearl, Ill.	12	(1)	(2)	23.0	19
Paducah, Ky.	43	24	29	44.0	26	<i>Grand:</i>					
Cairo, Ill.	45	(1)	(2)	53.5	25	Chillicothe, Mo.	18	10	11	19.1	10
<i>Conemaugh-Kiskiminetas:</i>						Brunswick, Mo.	10	10	14	12.6	11-12
Saltsburg, Pa.	8	16	16	9.5	16	<i>Osage:</i>					
<i>Muskingum:</i>						Osecola, Mo.	20	(1)	2	21.6	2
Zanesville, Ohio.	25	15	16	25.7	15		20	8	21	28.8	10
McConnellsville, Ohio.	22	15	16	25.0	16		22	(1)	6	26.8	4
<i>Tuscarawas:</i>						Warsaw, Mo.	22	8	22	34.9	12
Norris Point, Ohio.	8	(1)	2	8.6	1		22	28	(2)	25.3	28
Coshocton, Ohio.	8	15	19	11.7	16	Tusculum, Mo.	25	(1)	23	37.7	17
<i>Walhonding:</i>							25	20	(2)	27.4	30
Walhonding, Ohio.	8	15	16	11.2	15	<i>Meramec:</i>					
	8	18	18	9.0	18	Steelville, Mo.	12	18	18	13.1	18
<i>Hocking:</i>							11	(1)	3	17.9	3
Athens, Ohio.	17	15	16	21.9	16	Pacific, Mo.	11	11	13	12.3	11
<i>Scioto:</i>							11	17	20	17.4	20
La Rue, Ohio.	11	1	1	11.8	1	Valley Park, Mo.	14	(1)	4	21.0	3
	11	15	16	13.5	15		14	11	13	14.8	12
Prospect, Ohio.	10	1	1	10.3	1		14	15	21	22.8	19
	10	19	20	11.7	19	<i>Bourbeuse:</i>					
Circleville, Ohio.	10	1	1	10.0	1	Union, Mo.	10	1	3	14.4	2
Chillicothe, Ohio.	16	15	17	20.5	16		10	17	19	13.6	19
<i>Stillwater:</i>						<i>St. Francis:</i>					
Pleasant Hill, Ohio.	13	15	15	13.2	15	Marked Tree, Ark.	17	(1)	(2)	19.3	15-17
<i>Green:</i>						<i>Yazoo:</i>					
Lock No. 4, Woodbury, Ky.	33	3	3	33.0	3	Yazoo City, Miss.	25	(1)	(2)	31.9	29-30
<i>Wabash:</i>						<i>Tallahatchie:</i>					
Bluffton, Ind.	12	19	20	13.4	19	Swan Lake, Miss.	25	(1)	30	28.0	1
Lafayette, Ind.	11	(1)	6	21.0	2	<i>Red:</i>					
	11	9	23	20.7	18	Fulton, Ark.	28	8	10	28.5	9
Terre Haute, Ind.	16	(1)	26	24.4	19	Alexandria, La.	36	12	23	37.1	18-20
Vincennes, Ind.	14	(1)	(2)	23.0	21-22	<i>Ouachita:</i>					
Mount Carmel, Ill.	15	(1)	(2)	26.0	23	Camden, Ark.	30	(1)	13	36.2	4
<i>White:</i>						Monroe, La.	30	30	(2)	30.1	30
Decker, Ind.	18	(1)	27	25.7	22	<i>Atchafalaya:</i>					
<i>East Fork of White:</i>						Simmesport, La.	41	6	(2)	49.5	28-29
Williams, Ind.	10	3	5	11.8	4	Melville, La.	37	1	(2)	44.8	28
	10	15	22	17.4	19	<i>Missouri:</i>					
Shoals, Ind.	20	3	6	22.5	5	Hermann, Mo.	21	8	20	24.7	18
	20	15	23	28.0	19	St. Charles, Mo.	25	(1)	8	26.5	1
							25	8	22	30.8	13, 19
						<i>James:</i>					
						Huron, S. Dak.	9	(1)	(2)	12.1	1
						<i>Smoky Hill:</i>					
						Lindsborg, Kans.	19	26	27	21.4	27

Continued from March, 1922.

Continued into May, 1922.

Flood stages during April, 1922—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
MISSISSIPPI DRAINAGE—continued.					
Arkansas:	Feet.			Feet.	
Wichita, Kans.....	9	9	10	9.9	9
Fort Smith, Ark.....	22	10	17	27.8	12
Dardanelle, Ark.....	20	11	18	25.2	13
Little Rock, Ark.....	23	14	15	23.3	14
Pine Bluff, Ark.....	25	14	17	26.0	16
Neosho:					
Neosho Rapids, Kans.....	22	10	11	24.4	11
Le Roy, Kans.....	24	9	11	27.4	9
Iola, Kans.....	15	9	13	19.2	10
Oswego, Kans.....	17	5	17	23.8	9
Wyandotte, Okla.....	23	10	10	23.5	10
Fort Gibson, Okla.....	22	10	17	30.0	11
	22	19	19	22.4	19
Cottonwood:					
Emporia, Kans.....	20	10	12	22.9	11
North Canadian:					
Woodward, Okla.....	3	5	10	3.4	8
	3	25	(²)	5.0	25
Canton, Okla.....	3	26	26	3.7	26
Oklahoma City, Okla.....	12	10	10	12.6	10
Petit Jean:					
Danville, Ark.....	20	(¹)	3	22.7	2
	20	6	9	22.6	7
Little Arkansas:					
Sedgwick, Kans.....	18	28	9	23.5	9
White:					
Newport, Ark.....	26	13	14	26.2	13-14
Georgetown, Ark.....	22	(¹)	24	23.9	6-9, 11, 15
Clarendon, Ark.....	30	7	27	30.7	11-21
Black:					
Black Rock, Ark.....	14	(¹)	(²)	23.4	9
Cache:					
Patterson, Ark.....	9	(¹)	19	10.3	1
Sulphur:					
Finley, Tex.....	22	(¹)	16	26.4	2-3
	22	27	(²)	28.2	30
Ringo Crossing, Tex.....	20	6	10	23.0	6
	20	26	(²)	23.8	28
Cypress:					
Jefferson, Tex.....	18	2	8	21.6	4
	18	27	(²)	20.5	28
WEST GULF DRAINAGE.					
Sabine:					
Logansport, La.....	25	(¹)	(²)	34.7	2
Orange, Tex.....	4	8	24	5.0	17
Neches:					
Rockland, Tex.....	20	(¹)	17	28.9	2
	20	29	(²)	21.7	30
Beaumont, Tex.....	7	4	21	11.2	9-10
Trinity:					
Fort Worth, Tex.....	30	25	26	39.1	25
Dallas, Tex.....	25	4	9	36.5	5
	25	26	(²)	42.3	27
Trinidad, Tex.....	28	6	17	38.3	11
	28	26	(²)	38.8	30
Long Lake, Tex.....	40	9	16	41.7	9
	40	30	(²)	42.4	30
Liberty, Tex.....	25	(¹)	(²)	28.0	7-10
Brazos:					
Waco, Tex.....	27	4	5	33.3	4
	27	27	27	30.4	27
Valley Junction, Tex.....	44	5	7	49.4	6
	44	29	29	47.3	29
Washington, Tex.....	45	6	10	49.9	8
Hempstead, Tex.....	45	29	30	46.2	30
	40	8	11	42.7	9
Freeport, Tex.....	4	13	14	4.2	13-14
	4	16	17	4.2	16-17
COLORADO DRAINAGE.					
Colorado (Texas):					
Austin, Tex.....	18	27	(²)	21.2	28
Smithville, Tex.....	24	30	(²)	24.1	30
Columbus, Tex.....	28	5	7	31.7	6
	28	29	(²)	33.0	30
Guadalupe:					
Gonzales, Tex.....	22	5	6	33.3	5
	22	29	29	25.2	29
	16	1	3	21.0	3
Victoria, Tex.....	16	5	10	23.9	9
	16	30	(²)	17.2	30
Colorado:					
Lee's Ferry, Ariz.....	12	26	(²)	13.6	30
North Fork of Gunnison:					
Paonia, Colo.....	8	26	(²)	8.6	30

¹ Continued from March, 1922.² Continued into May, 1922.

MEAN LAKE LEVELS DURING APRIL, 1922.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., May 3, 1922.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes. ¹			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during April, 1922:	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Above mean sea level at New York.....	601.45	579.93	572.35	246.06
Above or below—				
Mean stage of March, 1922.....	+0.10	+0.53	+0.96	+0.98
Mean stage of April, 1921.....	-0.24	-0.41	-0.44	-0.32
Average stage for April, last 10 years.....	-0.37	-0.45	-0.12	-0.35
Highest recorded April stage.....	-1.24	-3.30	-1.83	-2.37
Lowest recorded April stage.....	+0.91	+0.71	+1.09	+1.22
Average relation of the April level to:				
March level.....		+0.30	+0.70	+0.70
May level.....		-0.30	-0.40	-0.30

¹ Lake St. Clair's level: In April, 575.08 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, APRIL, 1922.

By J. WARREN SMITH, Meteorologist.

The first half of April was warm for the season in the Central and Eastern States, but unseasonably cool weather persisted west of the Rocky Mountains, while the latter half of the month was cool in the east, with freezing temperatures extending southward well into the Appalachian Mountain districts.

The unseasonably cold and stormy weather in the more Western States was decidedly unfavorable for stock in that section, especially for young lambs, and considerable loss was reported. The warm weather in Eastern States had forced a rapid development of fruit bloom, and early varieties were coming into blossom in districts that were visited by freezing temperatures and killing frosts the latter part of the month. Much damage was done to fruit in the upper Ohio Valley and the central Appalachian districts by the freeze of April 22-24. Additional damage occurred to fruit in these sections during the following week, being rather heavy in central Ohio and West Virginia, and to grapes and early cherries in New York.

The weather continued generally favorable for winter wheat and other fall-sown grains east of the Rocky Mountains. The mild temperatures and abundant moisture caused rapid growth of winter wheat, while the rains early in the month favorably affected this crop in the Southwest. There was too much rain, however, in some central districts; and much wheat land was flooded in many low sections, while plants continued to show lack of vitality and stood poorly in western Kansas, due to the previous long winter drought.

Seeding of spring wheat and spring oats was further delayed in central and northern districts by frequent rains, but there was a marked improvement in soil condition the latter part of the month, which permitted of much better progress, especially in some large oat-producing sections of the upper Mississippi Valley. Spring-wheat seeding was pushed during the last two weeks of

the month and at its close was nearly completed in the central and eastern portions of the belt.

The month was generally favorable for planting corn in the Southern States, and warmth was sufficient to cause satisfactory germination in most sections, although it was too cool the latter part of the month, particularly in the Southeastern States. The soil was wet and unfavorable for preparation of corn ground in the Central Valley States during much of the month, although fairly good progress was made in the Great Plains sections. Planting was well along at the close of the month as far north as central Kansas in the latter area, but this work was much delayed in central Valley districts. Conditions were more favorable for field work in the cotton States during the middle and latter parts of the month and cotton planting made fairly good progress. The nights were too cool, however, the latter part of the

month in most sections for rapid germination, while excessive rains west of the Mississippi River were detrimental. Beneficial rains occurred in southern Georgia near the close of the month. In eastern districts the crop had advanced to a stage where it was ready to chop out on the coastal plain of South Carolina, and planting progressed during the last decade of the month to the extreme northwestern portion of the cotton-growing section of Texas.

Truck was seriously damaged in Florida by prolonged drought, and growth was slow in southern California on account of cool weather. Grass and meadows made satisfactory growth with favorable weather conditions in nearly all central and eastern localities, but moisture continued deficient in the far Southwest, while more rain was needed in the extreme Southeast and some central and northern areas.

CLIMATOLOGICAL TABLES.¹

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings:

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, April, 1922.

Section.	Temperature.						Precipitation.								
	Section average.	Departure from the normal.	Monthly extremes.				Section average.	Departure from the normal.	Greatest monthly.		Least monthly.				
			Station.	Highest.	Date.	Station.			Lowest.	Date.	Station.	Amount.	Station.	Amount.	
Alabama.....	66.9	+3.7	Tuskegee.....	92	15	Valley Head.....	32	22	4.14	-0.24	St. Bernard.....	8.14	Robertsdale.....	In.	0.61
Arizona.....	51.8	-1.0	Parker.....	99	22	Fort Valley.....	2	6	0.55	+0.02	Ryan Ranger Sta.....	2.40	9 stations.....	0.00	
Arkansas.....	63.4	+2.2	Huttig.....	90	7	Dutton.....	26	1	5.50	+0.72	Spring Bank.....	12.81	Hardy.....	2.77	
California.....	52.9	-4.1	Greenland Ranch.....	100	25	Fordyce Dam.....	-3	15	0.82	-0.97	Mesa Grande.....	4.95	12 stations.....	0.00	
Colorado.....	40.8	-2.2	2 stations.....	82	15	Silverton.....	-9	18	2.22	+0.30	Long Branch.....	5.81	Saguache.....	T.	
Florida.....	73.2	+3.4	2 stations.....	98	13	Wausau.....	38	5	0.89	-1.71	Tallahassee.....	4.41	4 stations.....	0.00	
Georgia.....	66.8	+3.4	St. George.....	96	14	Blue Ridge.....	28	2	3.56	0.00	Dahlonega.....	7.62	Tifton.....	0.30	
Hawaii.....	70.9	+0.9	Mahukona.....	89	30	Waimea.....	48	24	5.08	-2.46	Honolulu.....	23.49	3 stations.....	0.00	
Idaho.....	39.7	-1.2	2 stations.....	79	21	Stanley.....	-14	16	1.70	+0.28	Priest River Exp. Sta.....	3.59	Felt.....	0.28	
Illinois.....	53.9	+2.1	Sparta.....	85	6	2 stations.....	24	1	5.05	+1.64	Paris.....	9.93	Paw Paw.....	1.15	
Indiana.....	54.3	+2.6	2 stations.....	88	27	Huntingburg.....	23	2	6.08	+2.61	Whitestown.....	11.58	Hobart.....	3.13	
Iowa.....	49.9	+1.2	Thurman.....	87	6	Boone.....	21	1	3.06	+0.20	Algona.....	6.70	Inwood.....	1.04	
Kansas.....	54.9	+0.8	Medicine Lodge.....	87	21	Tribune.....	15	11	5.07	+2.62	Oswego.....	12.41	Ashland.....	0.92	
Kentucky.....	59.5	+3.6	Williamsburg.....	88	14	Berea.....	25	2	4.24	+0.30	Middlesboro.....	7.13	Irvington.....	2.68	
Louisiana.....	70.5	+3.5	Coushatta.....	91	13	Calhoun.....	37	1	4.34	-0.49	Coushatta.....	9.80	2 stations.....	1.59	
Maryland-Delaware.....	51.0	+1.4	Hancock, Md.....	93	10	Oakland, Md.....	17	24	1.90	-1.44	Oakland, Md.....	3.56	Baltimore, Md.....	0.88	
Michigan.....	43.0	+0.6	Kalamazoo.....	84	10	Humboldt.....	7	1	3.37	+1.07	Sack Bay.....	6.30	Iron River.....	1.50	
Minnesota.....	43.0	+0.1	Beardsley.....	83	24	Warroad.....	7	1	1.89	-0.16	Grand Meadow.....	4.19	Pipestone.....	T.	
Mississippi.....	67.7	+3.7	Okolona.....	91	7	Duck Hill.....	36	2	5.23	-0.23	Myrtle.....	10.60	Columbia.....	1.60	
Missouri.....	57.3	+1.9	Caruthersville.....	91	16	Bethany.....	24	1	6.21	+2.42	Warsaw.....	14.34	Bethany.....	1.72	
Montana.....	40.4	-3.9	Glasgow.....	83	22	Hebgen Dam.....	-10	15	1.84	+0.78	Adel.....	5.92	Knobles Ranch.....	0.51	
Nebraska.....	49.0	+0.2	Syracuse.....	87	6	Kimball.....	15	11	2.70	+0.22	Hay Springs.....	6.26	Santee.....	0.34	
Nevada.....	43.8	-5.5	2 stations.....	92	23	Owyhee.....	6	11	0.74	-0.01	Arthur.....	3.30	Mina.....	0.00	
New England.....	43.6	+1.0	2 stations.....	85	10	Somerset, Vt.....	10	2	2.87	-0.33	Somerset, Vt.....	5.07	Rutland, Mass.....	1.18	
New Jersey.....	51.0	+1.5	Paterson.....	89	10	2 stations.....	18	21	2.55	-1.08	Hightstown.....	4.12	Woodcliff Lake.....	1.57	
New Mexico.....	50.0	-0.8	Tularosa.....	89	25	Chama.....	4	18	1.30	+0.05	Texico (near).....	6.63	3 stations.....	0.00	
New York.....	45.3	+1.0	Mount Vernon.....	89	10	Indian Lake.....	3	4	3.12	+0.32	Wanakena.....	7.02	Lauterbrunnen.....	0.44	
North Carolina.....	60.4	+2.9	2 stations.....	96	14	Parker.....	23	23	3.70	+0.13	Monroe.....	7.41	Manteo.....	1.54	
North Dakota.....	42.3	+0.6	Mandan.....	89	23	3 stations.....	-2	18	0.92	-0.46	Wahpeton.....	3.15	Pembina.....	T.	
Ohio.....	52.6	+2.6	4 stations.....	86	7	2 stations.....	20	22	4.52	+1.32	Eaton.....	7.96	Madison.....	1.73	
Oklahoma.....	60.8	+0.8	Beaver.....	95	15	Goodwell.....	15	1	6.50	+3.52	Antlers.....	13.00	Goodwell.....	1.15	
Oregon.....	44.5	-3.2	The Dalles.....	83	23	Crater Lake.....	-3	17	2.36	-0.11	Larch Mountain.....	10.75	Madras.....	0.18	
Pennsylvania.....	50.1	+1.4	Gettysburg.....	91	10	West Bingham.....	11	22	3.17	-0.50	Herrs Island Dam.....	6.10	Lancaster.....	1.28	
South Carolina.....	64.5	+2.1	Garnett.....	95	14	Santuck.....	33	2	5.11	+2.14	Landrum.....	8.30	Garnett.....	0.82	
South Dakota.....	46.0	+0.8	4 stations.....	81	24	Deadwood.....	9	17	1.49	-0.69	Hermosa.....	4.34	Marion.....	T.	
Tennessee.....	61.8	+3.6	Moscow.....	92	14	Mountain City.....	23	23	5.44	+0.84	New River.....	8.61	Covington.....	3.14	
Texas.....	67.6	+1.8	San Benito.....	107	10	Clint.....	23	19	6.26	+3.04	Weatherford.....	18.11	Mercedes.....	0.00	
Utah.....	41.5	-5.8	St. George.....	86	22	4 stations.....	0	29	1.74	+0.53	Silver Lake.....	6.22	Kelton.....	0.12	
Virginia.....	57.0	+2.5	2 stations.....	93	10	Burkes Garden.....	19	23	2.22	-1.19	Mendota.....	5.71	Manassas.....	0.82	
Washington.....	45.4	-2.9	Granger.....	86	21	Lake Keechelus.....	9	12	2.21	+0.09	Cedar Lake.....	10.70	Wapato.....	0.00	
West Virginia.....	54.4	+2.9	Moorefield.....	91	10	Cheat Bridge.....	15	24	3.15	-0.37	Pickens.....	6.76	Upper Tract.....	0.50	
Wisconsin.....	43.3	+0.1	Racine.....	76	7	Long Lake.....	7	1	3.51	+1.05	Marshfield.....	5.62	Danbury.....	1.17	
Wyoming.....	36.4	-3.6	2 stations.....	76	24	Lake Yellowstone.....	-19	17	2.14	+0.51	Dome Lake.....	6.36	2 stations.....	0.16	

¹ For description of tables and charts, see REVIEW.

² Other dates also.

TABLE I.—Climatological data for Weather Bureau stations, April, 1922.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Precipitation.			Wind.										
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.-2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Total.		Days with .001 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity.			Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
																			In.	In.				Miles per hour.	Direction.	Date.						
New England.	Ft.	Ft.	Ft.	In.	In.	In.	* F.	* F.	* F	* F*	* F.	* F.	* F.*	* F.*	* F.	* F.	%	In.	In.		Miles.	s.							0-10	In.	In	
Eastport.....	76	67	85	29.86	29.95	+0.02	40.5	+2.2	67	8	47	27	1	34	30	36	32	76	1.76	-1.2	12	8,715	nw.	43	e.	12	2	10	18	7.7	1.0	0.0
Greenville, Me.....	1,070	6		28.79	29.97	....	39.4	....	64	25	48	18	23	30	34	....	....	2.99	....	13	7,423	nw.	38	nw.	27	6	4	20	....	7.6	....
Portland, Me.....	103	82	117	29.88	30.01	+0.05	44.6	+1.6	72	26	53	28	2	36	31	39	32	66	5.17	+2.1	10	4,939	nw.	31	nw.	27	12	10	8	5.1	14.1	0.0
Concord.....	288	70	79	29.68	30.00	+0.01	45.2	+1.4	83	10	56	27	22	35	42	....	....	2.11	-0.7	10	4,939	nw.	31	nw.	27	12	10	8	4.5	4.9	0.0	
Burlington.....	404	11	48	29.56	30.01	+0.02	42.8	+2.1	77	10	52	19	3	34	33	....	....	3.38	+1.5	11	8,588	s.	56	s.	7	6	11	13	6.3	8.9	0.0	
Northfield.....	876	12	60	29.06	30.03	+0.04	40.4	+0.2	76	10	52	14	3	29	40	37	32	74	2.88	+0.8	14	5,873	s.	39	sw.	11	6	13	11	6.3	16.6	0.0
Boston.....	125	115	188	29.87	30.01	+0.04	48.7	+2.3	85	10	58	29	2	40	30	43	37	66	2.48	-1.1	8	6,352	w.	35	se.	1	13	5	12	5.1	3.3	0.0
Nantucket.....	12	14	90	29.99	30.00	+0.03	45.5	+1.3	67	26	51	31	32	40	21	42	38	81	2.90	+0.3	12	12,175	sw.	48	se.	1	12	8	10	5.4	1.8	0.0
Block Island.....	26	11	46	29.98	30.01	+0.03	45.6	+1.8	70	10	52	30	2	39	30	41	38	82	2.79	-0.8	11	12,697	sw.	52	w.	20	13	4	13	5.1	T.	0.0
Providence.....	160	215	251	29.84	30.02	+0.04	48.3	+1.7	82	10	58	28	2	39	36	42	34	62	2.18	-1.6	9	10,012	nw.	53	w.	21	14	3	13	5.0	0.4	0.0
Hartford.....	159	122	140	29.85	30.03	+0.04	48.8	+2.1	84	10	59	30	2	39	37	42	35	65	2.46	-1.1	12	6,215	nw.	36	sw.	20	13	5	12	5.4	1.7	0.0
New Haven.....	106	74	153	29.93	30.04	+0.05	49.2	+2.8	82	10	58	31	22	40	39	42	34	60	3.06	-0.5	10	7,379	n.	38	nw.	27	14	5	11	4.9	T.	0.0
Middle Atlantic States.							53.1	+2.2									63	1.92	-1.1		"								5.4			
Albany.....	97	102	115	29.94	30.04	+0.04	48.0	+2.2	86	10	58	27	3	38	42	42	36	68	2.26	-0.1	9	5,853	s.	40	se.	17	15	5	10	4.6	T.	0.0
Binghamton.....	871	10	84	29.10	30.05	+0.03	46.8	+2.4	82	10	57	25	22	37	34	....	....	2.54	+0.3	14	5,015	nw.	31	w.	20	7	7	16	6.3	T.	0.0	
New York.....	314	414	454	29.71	30.05	+0.05	51.0	+2.9	82	10	60	31	21	42	24	44	36	62	1.96	-1.3	8	12,127	nw.	72	nw.	20	9	12	9	5.4	0.0	0.0
Harrisburg.....	374	94	104	29.68	30.09	+0.07	52.6	+1.9	86	10	61	31	22	44	28	45	36	57	1.43	-1.1	12	5,640	w.	44	sw.	11	11	6	13	5.9	T.	0.0
Philadelphia.....	117	123	190	29.96	30.08	+0.07	54.0	+3.2	87	10	63	34	22	45	25	46	37	56	1.52	-1.4	12	7,464	nw.	36	sw.	11	6	14	10	6.0	0.0	0.0
Reading.....	325	81	98	29.72	30.08	+0.07	52.4	....	85	10	61	31	22	43	30	46	39	63	1.88	-1.3	12	3,387	nw.	36	nw.	20	10	9	11	5.2	0.0	0.0
Scranton.....	805	111	119	29.21	30.08	+0.07	48.6	+1.5	82	10	58	26	22	39	36	42	37	68	1.44	+0.8	14	6,038	nw.	48	sw.	11	8	12	10	6.1	0.1	0.0
Atlantic City.....	52	37	48	30.02	30.08	+0.08	49.4	+1.8	85	10	56	30	3	42	31	45	40	73	1.75	-1.2	10	13,263	nw.	56	s.	11	13	9	8	4.8	0.0	0.0
Cape May.....	18	13	49	30.09	30.01	+0.02	51.3	+2.9	83	10	58	35	3	44	34	45	41	74	2.41	-0.6	12	7,335	nw.	41	sw.	11	13	8	9	4.9	0.0	0.0
Sandy Hook.....	22	10	55	30.03	30.05	+0.02	49.6	....	81	10	57	35	21	42	34	43	37	67	2.08	....	9	11,360	w.	56	sw.	11	11	7	12	5.0	0.0	0.0
Trenton.....	190	159	183	29.86	30.06	+0.05	51.6	....	83	10	61	30	22	42	29	47	43	73	1.69	-1.6	11	9,055	w.	52	w.	20	9	11	10	5.6	0.0	0.0
Baltimore.....	123	100	113	29.96	30.09	+0.08	55.8	+2.8	89	10	64	34	22	47	35	48	39	57	0.88	-2.4	9	4,635	sw.	31	sw.	11	7	11	12	6.0	0.0	0.0
Washington.....	112	62	85	29.96	30.09	+0.07	55.6	+2.5	89	10	65	33	22	46	43	48	39	55	1.05	-2.2	9	5,556	nw.	33	nw.	1	8	10	12	5.8	0.0	0.0
Lynchburg.....	681	153	188	29.36	30.10	+0.08	57.8	+0.5	89	10	69	32	24	46	41	50	44	66	1.53	-1.6	12	6,202	sw.	38	sw.	11	12	6	4.5	0.0	0.0	
Norfolk.....	91	170	205	30.01	30.11	+0.10	59.7	+3.7	87	10	68	39	25	51	35	52	46	66	1.88	-1.9	7	10,141	ne.	50	sw.	11	11	10	9	5.2	0.0	0.0
Richmond.....	144	11	52	29.95	30.10	+0.08	58.6	+1.4	88	10	69	36	24	48	39	51	44	64	2.01	-1.4	10	6,918	s.	46	sw.	11	11	10	9	4.9	0.0	0.0
Wytheville.....	2,304	49	56	27.73	30.11	+0.08	53.8	+1.8	81	10	64	29	23	44	36	47	42	69	2.51	-1.2	11	5,547	w.	36	sw.	11	10	12	8	4.8	0.0	0.0
South Atlantic States.							64.3	+2.8									73	3.16	-0.2										4.8			
Asheville.....	2,255	70	84	27.76	30.11	+0.08	57.1	+3.2	85	14	68	30	2	47	37	49	44	68	3.37	-0.7	11	6,860	nw.	42	e.	28	10	12	8	4.7	0.0	0.0
Charlotte.....	779	55	62	29.27	30.11	+0.08	61.0	+1.8	86	13	70	38	2	52	31	54	48	70	6.59	+3.2	10	4,572	sw.	23	sw.	11	11	6	13	5.5	0.0	0.0
Hatteras.....	11	11	50	30.09	30.10	+0.09	60.8	+2.8	84	15	67	41	25	55	24	56	52	76	2.27	-2.1	6	12,458	sw.	48	sw.	11	11	10	9	5.1	0.0	0.0
Manteo.....	12	5	42	....	....	....	61.4	....	90	14	71	30	25	52	30	....	....	....	1.54	....	5	....	ne.	....	....	18	5	7	....	0.0	0.0	
Raleigh.....	376	103	110	29.70	30.10	+0.07	61.0	+2.0	90	14	71	39	2	51	34	55	50	73	2.57	-0.9	9	7,244	sw.	44	sw.	11	11	9	10	4.9	0.0	0.0
Wilmington.....	78	81	91	30.04	30.12	+0.09	63.7	+3.3	91	14	73	41	24	55	27	58	54	76	3.26	+0.4	11	7,169	sw.	35	sw.	11	13	6	11	5.0	0.0	0.0
Charleston.....	48	11	92	30.07	30.12	+0.09	68.2	+3.7	89	15	76	45	29	60	31	60	57	74	1.50	-1.5	6	8,844	sw.	33	ne.	28	13	11	6	4.1	0.0	0.0
Columbia, S. C.....	351	41	57	29.74	30.13	+0.10	64.4	+1.6	90	14	75	41	29	54	31	56	52	70	6.53	+3.7	11	5,520	sw.	37	sw.	11	12	6	12	5.5	0.0	0.0
Due West.....	711	10	55	29.36	30.13	+0.06	62.6	....	87	14	73	39	2	52	33	....	....	....	6.05	....	8	7,002	sw.	35	sw.	14	8	12	10	5.7	0.0	0.0
Greenville, S. C.....	1,039	113	122	29.00	30.10	+0.06	61.7	....	85	14	71	40	28	52	31	54	48	67	4.97	....	10	7,671	sw.	39	sw.	11	10	11	9	5.2	0.0	0.0
Augusta.....	180	62	77	29.91	30.10	+0.07	66.1	+1.9	90	14	77	44	29	56	35	59	55	73	3.03	-0.5	7	4,384	s.	24	n.	5	9	10	11	5.7	0.0	0.0
Savannah.....	65	150	194	30.05	30.12	+0.09	69.0	+4.3	90	14	74	44	29	60	31	62	59	79	1.07	-1.9	4	9,156	s.	35	sw.	11	17	7	6	3.7	0.0	0.0
Jacksonville.....	43	209	245	30.07	30.12	+0.08	71.4	+3.8	90	14	79	51	30	64	23	63	59	72	1.39	-1.3	3	9,236	s.	38	sw.	11	15	11	4	3.8	0.0	0.0
Florida Peninsula.							76.6	+3.0									72	0.26	-1.6										3.8			
Key West.....	22	10	64	30.05	30.07	+0.05	78.8	+3.1	86	29	83	71	2	74	13	70	66	70	0.08	-1.2	4	8,346	se.	26	se.	8	20	8	2	3.0	0.0	0.0
Miami.....	25	71	79	30.09	30.12	+0.05	75.8	+1.6	84	12	80	62	2	72	16	68	65	71	0.54	-2.0	6	6,837	se.	25	e.	24	13	11	6	4.7	0.0	0.0
Sand Key.....	23	39	72	30.06	30.09	+0.07	76.4	....	82	29	78	71	2	75	6	70	67	73	0.01	....	1	11,129	se.	37	e.	24	19	9	2	2.9	0.0	0.0

TABLE I.—Climatological data for Weather Bureau stations, April, 1922—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.				
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. +2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.							Maximum velocity.			
																														Miles per hour.	Direction.	Date.	
Ohio Valley and Tennessee.	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	%	In.	In.	Miles.			Miles per hour.	Direction.	Date.							
							57.3	+2.8										68	4.55	+1.0													
Chattanooga.	762	189	213	29.28	30.10	+0.07	62.7	+2.7	85	14	72	39	2	53	31	54	49	67	4.35	0.0	15	6,740	n.	44	sw.	11	7	11	12	6.0	0.0	0.0	
Knoxville.	996	102	111	29.04	30.09	+0.06	61.0	+3.6	85	14	71	36	2	52	32	53	47	65	4.61	0.0	15	5,787	sw.	42	sw.	11	5	9	16	6.8	0.0	0.0	
Memphis.	399	76	97	29.64	30.07	+0.07	64.0	+4.0	83	16	72	42	1	56	27	57	51	65	3.21	-1.6	10	7,272	s.	56	sw.	11	9	6	15	6.3	0.0	0.0	
Nashville.	546	168	191	29.49	30.08	+0.07	61.6	+2.5	84	14	71	38	1	52	29	56	51	71	4.53	+0.2	11	8,409	s.	54	nw.	14	4	13	13	6.5	0.0	0.0	
Lexington.	989	193	230	29.02	30.09	+0.07	57.0	+3.3	81	8	66	34	1	48	30	56	51	71	4.46	+1.1	9	12,105	sw.	58	s.	11	12	5	13	5.4	0.0	0.0	
Louisville.	525	219	255	29.49	30.08	+0.07	59.3	+3.1	84	7	69	35	1	49	31	52	48	70	6.06	+2.0	8	9,967	s.	54	s.	17	11	9	10	5.3	0.0	0.0	
Evansville.	431	139	175	29.59	30.06	+0.06	59.2	+2.8	84	8	69	36	1	49	32	52	45	64	4.07	+0.6	10	9,760	sw.	55	w.	11	5	17	8	5.9	0.0	0.0	
Indianapolis.	822	194	230	29.16	30.05	+0.05	54.2	+1.8	78	7	64	32	1	44	31	48	43	70	8.55	+5.1	13	9,770	se.	54	w.	19	10	7	13	5.9	0.0	0.0	
Royal Center.	736	11	55	29.24	30.05	.....	50.4	.....	76	10	60	28	1	41	32	.....	.....	.....	4.71	.....	15	8,482	se.	50	w.	19	10	4	16	6.2	0.1	0.0
Terre Haute.	575	96	129	29.40	30.02	.....	55.8	.....	77	9	65	32	1	46	32	51	48	80	10.57	.....	12	8,216	s.	50	s.	8	9	11	10	5.9	0.0	0.0
Cincinnati.	628	11	51	29.40	30.08	+0.07	55.6	+3.3	83	7	66	33	20	45	32	46	72	4.32	+1.4	11	6,600	ne.	46	sw.	11	8	15	7	5.3	T.	0.0		
Columbus.	824	179	222	29.20	30.08	+0.06	53.1	+2.1	79	10	63	30	22	44	31	47	62	69	3.05	+0.2	8	9,312	nw.	53	nw.	17	9	12	9	5.3	T.	0.0	
Dayton.	899	181	216	29.08	30.04	.....	54.2	+2.5	79	10	64	33	1	44	33	48	43	72	5.38	+2.5	11	8,907	no.	52	w.	11	10	14	6	5.1	0.0	0.0
Elkins.	1,947	59	67	28.04	30.10	+0.07	51.8	+3.1	81	10	64	24	24	40	43	44	39	66	3.77	+0.5	13	4,963	w.	33	nw.	14	4	14	12	6.6	T.	0.0	
Parkersburg.	638	77	84	29.44	30.10	+0.07	56.2	+3.2	83	10	67	32	22	46	36	48	41	62	3.81	+0.9	10	5,030	n.	35	sw.	11	8	8	14	6.3	0.0	0.0	
Pittsburgh.	842	353	410	29.17	30.09	+0.07	52.6	+1.4	80	10	62	29	22	43	31	45	39	64	3.56	+0.7	15	9,006	nw.	47	nw.	20	5	11	14	6.6	3.0	0.0	
Lower Lake Region.							47.1	+1.9										73	2.72	+0.4													
Buffalo.	767	247	280	29.22	30.06	+0.05	44.8	+2.5	72	7	58	25	21	37	28	42	39	83	1.56	-0.9	12	13,784	sw.	80	w.	20	6	9	15	6.6	T.	0.0	
Canton.	448	10	61	29.51	29.99	.....	43.6	+1.1	72	10	53	20	21	35	27	.....	.....	.....	3.46	+1.2	13	8,361	w.	48	w.	18	15	5	10	5.1	14.2	0.0
Oswego.	335	76	91	29.40	30.04	+0.03	44.2	+1.0	72	10	51	26	20	37	27	.....	.....	.....	3.03	+1.4	15	8,312	w.	40	nw.	20	9	9	12	5.1	T.	0.0
Rochester.	523	89	102	29.48	30.07	+0.06	46.8	+1.9	75	9	56	26	21	38	28	40	33	64	2.40	0.0	13	7,397	w.	45	w.	20	9	9	12	5.8	0.4	0.0	
Syracuse.	597	97	113	29.40	30.05	+0.04	45.9	+1.5	79	10	54	25	21	38	29	.....	.....	.....	2.47	+0.2	13	9,591	nw.	46	w.	20	6	8	16	6.3	7.7	0.0
Erie.	714	130	166	29.29	30.07	+0.05	47.7	+3.0	78	9	56	29	22	40	32	43	38	71	2.45	0.0	13	11,598	w.	65	w.	19	8	11	11	5.6	0.1	0.0	
Cleveland.	762	190	201	29.25	30.08	+0.06	48.6	+3.7	79	7	57	30	22	41	28	43	39	72	2.10	-0.2	15	10,270	no.	66	w.	20	8	12	10	5.7	0.2	0.0	
Sandusky.	629	62	103	29.38	30.07	+0.05	49.0	+1.7	80	7	57	32	20	41	30	.....	.....	.....	3.02	+0.5	13	10,162	sw.	56	w.	11	8	11	11	5.5	0.8	0.0
Toledo.	628	208	243	29.38	30.07	+0.06	49.0	+1.4	80	7	57	30	20	41	27	44	40	75	3.33	+1.0	14	11,408	sw.	68	sw.	17	10	10	10	5.4	2.1	0.0	
Fort Wayne.	856	113	124	29.13	30.06	.....	50.8	+1.5	78	10	60	29	1	42	28	45	40	70	3.99	.....	14	7,642	sw.	56	s.	17	5	9	16	6.7	0.1	0.0
Detroit.	730	218	245	29.26	30.06	+0.04	48.1	+2.6	79	10	57	29	1	39	31	43	38	72	2.74	+0.4	11	8,934	sw.	56	w.	19	9	10	11	5.4	0.8	0.0	
Upper Lake Region.							42.3	+1.5										75	3.33	+1.0													
Alpena.	609	13	92	29.37	30.04	+0.02	40.8	+2.8	71	7	48	22	21	33	33	37	32	76	2.78	+0.6	10	8,757	nw.	54	nw.	20	9	10	11	6.0	2.5	0.0	
Escanaba.	612	54	66	29.36	30.05	+0.03	38.1	+0.9	65	7	45	23	1	32	29	34	31	80	4.23	+2.2	12	6,967	s.	42	ne.	11	8	9	13	5.9	4.1	0.0	
Grand Haven.	632	54	69	29.34	30.04	+0.03	44.6	+0.6	71	16	5	28	27	36	33	40	36	76	2.02	-0.4	9	8,771	s.	63	w.	19	9	11	10	5.5	0.1	0.0	
Grand Rapids.	707	70	87	29.27	30.05	+0.03	48.0	+1.8	74	7	58	29	1	38	33	42	36	67	4.50	+2.0	9	5,031	w.	34	w.	19	9	7	14	6.0	T.	0.0	
Houghton.	684	62	99	29.30	30.04	+0.02	38.1	+1.2	66	24	4	22	20	31	34	.....	.....	.....	2.62	+0.6	11	7,211	e.	50	no.	9	8	3	19	6.8	6.7	0.0
Lansing.	878	11	62	29.08	30.04	.....	46.8	+1.2	80	10	58	25	1	36	34	42	37	73	3.75	+1.2	9	5,365	w.	32	sw.	19	9	10	11	5.7	T.	0.0
Ludington.	637	60	66	29.35	30.04	.....	42.2	.....	70	16	49	27	28	35	33	39	36	81	2.39	.....	14	7,856	s.	42	s.	9	12	6	12	5.2	0.5	0.0
Marquette.	724	77	111	29.25	30.07	+0.05	37.9	+0.4	69	24	4	24	21	31	29	34	31	77	3.79	+1.8	11	6,504	nw.	38	nw.	19	8	4	18	6.9	15.9	0.0	
Port Huron.	638	70	120	29.34	30.04	+0.02	45.0	+2.8	76	10	54	28	1	36	35	40	36	74	3.39	+1.3	10	9,144	ne.	50	w.	19	9	14	7	4.6	0.2	0.0	
Saginaw.	641	69	77	29.34	30.04	.....	45.7	.....	74	7	56	26	1	36	35																	

TABLE 1.—Climatological data for Weather Bureau stations, April, 1922—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + min. +2.	Departure from normal.	Maximum.	Date.	Mean minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of dew-point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch, or more.	Total movement.	Prevailing direction.	Maximum velocity.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
																							Miles per hour.	Direction.							Date.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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	Fi.	Fi.	Fi.	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	%	In.	In.		Miles.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									

TABLE II.—Data furnished by the Canadian Meteorological Service, April, 1922.

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the Air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Depart- ure from normal.	Mean max.+ mean min.+2.	Depart- ure from normal.	Mean maxi- mum.	Mean mini- mum.	Highest.	Lowest.	Total.	Depart- ure from normal.	Total snowfall.
	Fert.	In.	In.	In.	° F	° F	° F	° F	° F	° F	In.	In.	In.
St. Johns, N. F.	125												
Sydney, C. B. I.	48												
Halifax, N. S.	88												
Yarmouth, N. S.	65												
Charlottetown, P. E. I.	38												
Chatham, N. B.	28												
Father Point, Que.	20	29.93	29.95	+0.02	35.3	+2.1	42.8	27.8	68	18	1.84	+0.26	5.2
Quebec, Que.	296	29.66	29.99	.00	39.9	+4.8	48.3	31.5	66	25	3.33	+1.24	2.5
Montreal, Que.	187	29.77	29.98	-.02	42.4	+2.7	50.3	34.4	66	24	4.75	+2.51	8.2
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.74	30.01	-.01	43.7	+3.7	54.4	33.1	74	24	3.65	+2.15	13.1
Kingston, Ont.	285	29.70	30.02	.00	42.8	+2.8	50.8	34.9	64	25	4.26	+2.47	10.9
Toronto, Ont.	379	29.63	30.04	+0.02	45.4	+4.6	55.0	35.9	78	25	3.77	+1.40	0.2
Cochrane, Ont.	930												
White River, Ont.	1,244	28.68	30.02	-.02	33.1	+0.1	43.1	23.1	60	8	2.25	+1.00	10.1
Port Stanley, Ont.	592	29.45	30.11	+0.09	44.6	+3.6	54.3	35.0	67	22	1.77	-0.70	4.2
Southampton, Ont.	656	29.31			41.8	+3.1	50.1	33.6	71	24	4.60	+2.80	1.5
Parry Sound, Ont.	688	29.31	30.01	-.01	42.8	+5.2	51.3	30.3	63	18	4.62	+2.71	6.1
Port Arthur, Ont.	644	29.33	30.04	+0.01	36.7	+3.2	44.0	29.4	67	15	0.88	-0.84	1.4
Winnipeg, Man.	760	29.19	30.04	+0.02	41.5	+5.6	52.3	30.7	72	16	0.52	-0.53	1.6
Minnedosa, Man.	1,690	28.19	30.04	+0.03	40.0	+4.0	51.4	28.7	76	9	0.34	-0.72	2.5
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.71	29.98	-.01	38.2	+0.8	48.8	27.7	76	11	1.96	+0.91	14.8
Medicine Hat, Alta.	2,144	27.63	29.91	-.01	42.9	-1.6	53.9	32.0	68	21	1.54	+0.80	8.2
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.43	30.08	+0.12	40.6	-0.7	51.4	29.8	74	16	0.68	-0.25	
Calgary, Alb.	3,428												
Banff, Alb.	4,521	25.33	29.96	+0.06	34.8	-1.5	44.7	24.9	62	13	1.09	+0.61	
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.43	30.02	+0.04	39.8	+3.7	51.1	28.5	74	13	1.20	+0.37	0.7
Battleford, Sask.	1,592	28.23	29.98	+0.01	42.1	+4.9	53.9	30.4	77	11	0.60	+0.13	1.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.87	30.13	+0.12	46.5	-0.3	52.7	40.2	67	35	0.73	-1.64	

LATE REPORTS—MARCH, 1922.

Kamloops, B. C.	1,262	28.65	29.97	+0.05	36.8	+0.7	46.1	27.5	57	11	0.36	-0.21	3.5
Banff, Alb.	4,521	25.18	29.89	-0.05	22.8	+2.6	33.8	11.8	42	-21	1.10	-0.31	11.0
Edmonton, Alb.	2,150	27.53	29.87	-0.09	22.4	-1.8	34.1	10.8	52	-11	0.57	-0.15	5.7
Calgary, Alb.	3,428	26.26	29.94	-0.01	26.0	-0.2	38.5	13.5	52	-15	0.51	-0.21	5.1
Medicine Hat, Alb.	2,144	27.56	29.87	-0.13	29.0	+1.5	39.2	18.8	58	0	0.32	-0.44	3.2

SEISMOLOGICAL REPORTS FOR APRIL, 1922.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, June 3, 1922.]

TABLE I.—Noninstrumental earthquake reports, April, 1922.

Day.	Approximate time, Green- wich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi- Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
CALIFORNIA.										
1922.	H. m.		° ' "	° ' "			Sec.			
13	4 12	Yorba Linda	33 50	117 45	3	1	4-5	None	No damage.	P. J. Ton.
16	5 30	Santa Ana	33 45	117 45		1	5		Felt by several.	Press.
26	0 12	Riverside	33 58	117 21		1	1-10	None	do.	Van Court Warren.
		Calexico	32 41	115 30	3	1				W. S. Pratt.
ILLINOIS.										
11	5 00	Monmouth	40 50	90 40	2	2	30	do.	Felt by one.	R. P. Hughes.
SOUTH CAROLINA.										
9	16 58?	Summerville	33 05	80 15	1			Faint	Felt by several.	E. G. Robertson.

LATE REPORTS.

OREGON.										
Jan. 31	13 20	Crater Lake	42 50	122 00	4	1	Few	Faint	Felt by one.	Mrs. W. T. Norris.

TABLE 2.—Instrumental seismological reports, April, 1922.

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols, see REVIEW for January, 1922.]

Date.	Char-acter.	Phase.	Time.	Period T.	Amplitude.		Dis- tance.	Remarks.
					A _H	A _N		
ALASKA. U. S. C. & G. S. Magnetic Observatory, Sitka.								
1922. Apr. 2			H. m. s.	Sec.	μ	μ	Km.	
		ce.	19 17 25					
		cn.	19 19 39					
		Ln.	19 20 43					
		M _N .	19 24 04	16	10			
		M _N .	19 19 58			30		
		F _N .	19 44 00					
		F _N .	19 23 00					
8								
		ce.	21 02 11					
		cn.	21 10 46					
		M _N .	21 07 04	21	20			
		F _N .	21 19 00					
		F _N .	21 14 00					
13								
		eP _N .	15 08 03					
		eP _N .	15 08 11					
		Ln.	15 08 29					
		M _N .	15 08 31	7	100			
		F _N .	15 14 00					
		F _N .	15 12 00					

ARIZONA. U. S. C. & G. S. Magnetic Observatory, Tucson.

1922.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 2	-----	e _N	1 54 51					
		e _N	1 54 28					
		M _N	1 55 07	6	20			
		M _N	1 54 53	5		20		
		F _N	2 02 00					
		F _N	2 00 00					
2	-----	e.....	19 26 12					
		eL _N	19 39 10					
		eL _N	19 41 25					
		M _N	19 44 48	17	10			
		M _N	19 41 56	18		10		
		F _N	20 25 00					
		F _N	19 59 00					
8	-----	eL _N	21 14 04	20				
		M _N	21 20 44	12	130	50		Times of phases in-
		F _N	21 34 00					determinate on
								E because of ir-
								regular motion of
								drum.
11	-----	eL _N	1 02 25	20				No record on N.
		M _N	1 06 50	17	10			
		F _N	1 33 00					
20	-----	P.....	6 00 15					
		L _N	6 00 44					
		L _N	6 00 49	5				
		M _N	6 00 51	7	110			
		M _N	6 03 21			130		
		F _N	6 14 00					
		F _N	6 10 00					
25	-----	eL _N	22 03 15					Do.
		L ₂	22 13 10					
		L ₃	22 26 06					
		M _N	22 30 52	17	20			
		F _N	22 55 00					

COLORADO. Regis College, Denver.

1922.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 8	-----	L	21 07 00					No P visible; sinu-
		M	21 09 00	24	*2,000	*1,500		soidal; weak but
		C	21 11 00					certainly seismic.
		F	21 13 00					
15	-----	L _N	23 08 00					Small, irregular
		F _N	23 20 00					waves; doubtful
								as to being seis-
								mic.
16	-----	L _N	0 02 00					Do.
		F _N	0 10 00					

* Trace amplitude.

TABLE 2.—Instrumental seismological reports, April, 1922—Continued.

Date.	Char-acter.	Phase.	Time.	Period T.	Amplitude.		Dis- tance.	Remarks.
					A _E	A _N		
DISTRICT OF COLUMBIA. U. S. Weather Bureau, Washington.								
1922. Apr. 2			H. m. s.	Sec.	μ	μ	Km.	E-W does not show.
		e.	17 13 18					
		L?	17 20 40					
		F.	17 30 ca.					
2								
		e.	19 35 18					
		L?	19 48 40					
		L.	19 55 ..	16				
		F.	20 40 ..					
5								
		e.	10 21 50					
		L.	11 05 ..	25				
		L.	11 11 ..	18				
		F.	11 50 ..					
6								
		e.	3 30 50					
		F.	3 55 ..					
6								
		e.	8 18 35					
		F.	8 40 ..					
8								
		P.	20 51 20					
		S.	20 58 42				5700	
		L.	21 07 15	20				
		L.	21 11 40	18				
		F.	22 10 ca.					
11								
		eL.	1 21 ..	20	*			
		F.	1 30 ..					
13								
		e.	15 18 ..					No phases.
		F.	15 50 ..					
17								
		e.	7 29 22					Minute.
		F.	7 35 ..					
20								
		e.	5 59 ..					No phases.
		F.	6 35 ..					
25								
		eL.	22 21 ..	20				
		L.	22 34 ..	16				
		F.	23 15 ca.					
26								
		e.	4 17 30					
		eL.	4 53 ..	16				
		L.	5 05 ..					
		F.	5 25 ca.					

HAWAII. U. S. C. & G. S. Magnetic Observatory, Honolulu.

1922. Apr. 2		P _N	H. m. s.	Sec.	μ	μ	Km.	
		iL.....	18 52 38					
		M _N	19 29 42	9				
		M _N	19 33 49		*24000			
		M _N	19 35 44	8		*20000		
		F.....	20 50 ..					
5		L.....	10 19 16					
		M _N	10 36 10		*5000			
		M _N	10 27 30			*3200		
		F _N	11 23 ..					
		F _N	11 30 ..					
8		eL _N	21 26 45					
		L _N	21 23 07					
		M _N	21 33 00		*2000			
		M _N	21 32 00	20		*3000		
		F _N	21 41 ..					
		F _N	21 44 ..					
10		en.....	4 12 40					Nothing definite.
		en.....	4 10 40					
		F.....	4 28 ..					
11		e.....	0 35 02					Sensitivity of in-
		L _N	0 45 10					strument before
		L _N	0 41 56	20				Apr. 15, N, 28.6
		M _N	0 46 26	20	*2200			mm; E, 24.5 mm;
		M _N	0 48 20	16		*1800		after Apr. 15, N,
		F _N	1 33 ..					28.5 mm; E, 23.8
		F _N	1 30 ..					mm.
25		S _N	21 33 18	6				E record lost by
		eSR _N	21 40 00					overlapping of
		L _N	21 44 55	20				traces.
		M _N	21 49 40	21		*2500		
		M _N	22 06 39			*2600		
		F _N	22 58 ..					

* Trace amplitude.

TABLE 2.—Instrumental seismological reports, April, 1922—Continued.

HAWAII. U. S. C. & G. S. Magnetic Observatory, Honolulu—Contd.

1922.		P.	H. m. s.	Sec.	μ	μ	Km.	Activity on E
Apr. 26		P _N	1 28 54	6				barely perceptible.
		S _N	1 33 16	10				
		L _N	1 36 06	10				
		M _N	1 39 ..	14		1300		
		F _N	1 42 ..					
26		P.	4 14 39	8				
		S.	4 20 31	10				
		L.	4 23 32					
		M.	4 23 13	10	2400			
		M.	4 20 45	10		3700		
		F.	5 54 ..					
		F.	5 21 ..					

ILLINOIS. U. S. Weather Bureau, Chicago.

1922.		P.	H. m. s.	Sec.	μ	μ	Km.	Activity on E
Apr. 2		P.	17 05 18				5500	
		S.	17 12 28					
		L.	17 19 50					
		F.	17 50 ..					
2		P.	19 26 47				5600	Lost in micros.
		S.	19 34 00					
		L.	19 42 05					
		M.	19 48 30		15000			
		F.	21 30 ca					Do.
5		P.	10 19 55				10600	
		S?	10 31 20					
		L?	10 54 ..					
		L.	11 00 ..	20				
		L.	11 15 ..	15				
		F.	13 ca ..					
6		IP.	3 30 40					
		PR.	3 32 38					
		S?	3 36 30					
		L.	3 45 ..	16				
		F.	4 20 ca					
6		P.	8 18 28					
		PR.	8 20 27					
		S?	8 24 30					
		L.	8 33 30	18				
		F.	9 10 ca					
8		eL.	4 55 ..					
		L.	4 58 35	18				
		F.	5 35 ..					
8		P.	20 50 59				5200	
		S.	20 57 50					
		L.	21 04 50					
		M.	21 08 20		*9000			
		F.	22 40 ca					
10		eL.	4 49 ..	22				
		L.	5 00 ..	16				
		F.	5 15 ca					
11		P?	0 46 43					
		S?	0 52 35					
		L.	1 13 ..	24				
		L.	1 23 ..	16				
		F.	2 15 ca					
13		e.	15 16 ..					
		S.	15 20 03					
		F.	16 ca ..					
16		eL.	14 00 11	18				
		F.	14 30 ca					
20		P.	5 54 33				3200	
		S.	5 59 30					
		L.	6 06 ..					
		F.	7 ca ..					
25		P.	21 44 18					
		PR.	21 47 33					
		S.	21 54 00					
		L?	22 08 ..					
		L.	22 13 ..	22				
		L.	22 18 ..	18				
		L.	22 28 ..	16				
26		F.	1 30 ca					
26		e.	1 34 30					
		L.	1 59 ..	22				
		F.	2 20 ca					
26		P?	4 19 26					
		S.	4 26 42					
		L?	4 35 10					
		L.	4 44 ..	18				
		F.	6 10 ca					
28		e.	5 46 20					
		F.	6 ca ..					
28		P?	7 24 ..					Feeble.
		L.	7 33 ..	16				
		F.	9 40 ca					

* Trace amplitude.

TABLE 2.—Instrumental seismological reports, April, 1922—Continued.

MARYLAND. U. S. C. & G. S. Magnetic Observatory, Cheltenham.

1922.		P.	H. m. s.	Sec.	μ	μ	Km.	Activity on E
Apr. 2		eL.	19 46 51					
		eL.	19 36 03	14				
		M.	19 51 20		10			
		M.	19 54 26	13		30		
		F.	20 14 ..					
		F.	20 30 ..					
5		eL.	11 00 21					
		eL.	11 03 40					
		M.	11 06 48	25	10			
		M.	11 10 33	18		10		
		F.	11 29 ..					
8		P.	20 51 02				5,000	Analysis uncertain.
		PR.	20 52 51					
		S.	20 57 55					
		S.	20 57 41					
		SR.	21 01 10					
		e.	21 03 00					
		e.	21 03 31					
		L.	21 07 51	17				
		M.	21 08 54	14	90			
		M.	21 11 00	13		40		
		F.	21 22 ..					
		F.	21 47 ..					
11		eL.	1 20 24					No record on N.
		M.	1 22 05	20	10			
		F.	1 38 ..					
13		eP.	15 22 55					
		eP.	15 23 32					
		L.	15 24 48	2				
		L.	15 25 03	3				
		M.	15 25 29		10			
		M.	15 25 08	3		20		
		F.	15 37 ..					
		F.	15 33 ..					
25		eL.	22 41 50					
		M.	22 45 30	17	10			
		F.	23 06 ..					

MISSOURI. St. Louis University, St. Louis.

1922.		P.	H. m. s.	Sec.	μ	μ	Km.	Activity on E
Apr. 2		eP.	19 26 56					
		eS.	19 34 11				5,600	This disturbance preceded by intermittent long waves for 2 hrs. ca.
		L.	19 42 57					
		F.	20 20 ..					
8		IP.	20 51 30?					High wind interfered with N-S component.
		S.	20 56 06				4,600	
		L.	21 02 36					
		M.	21 10 20	18	12			
		F.	21 38 ..					
13		eP.	15 17 48				2,700	L uncertain.
		S.	15 22 12					
		F.	15 36 ..					

NEW YORK. Cornell University, Ithaca.

1922.		P.	H. m. s.	Sec.	μ	μ	Km.	Activity on E
Apr. 2		eP?	19 27 30	5				Micros present.
		S.	19 35 18	6				
		eL.	19 45 ..					
		L.	19 50 ..	15				
		F.	20 26 ..					
5		L.	11 05 ..	20				
		F.	11 40 ..					
8		eP.	20 52 14	5				
		S.	20 57 06					
		eL?	21 00 ..	12				
		L.	21 02 ..	28				
		F.	21 45 ..					
11		L.	1 20 ..	20				
		F.	1 35 ..					
13		e.	15 22 48	3				
		F.	15 41 ..					
25		L.	22 22 ..	20				
		L.	22 41 ..	20				
		F.	23 18 ..					
26		L.	4 50 ..	18				
		F.	5 16 ..					

PORTO RICO. U. S. C. & G. S. Magnetic Observatory, Vieques.

1922.		P.	H. m. s.	Sec.	μ	μ	Km.	Activity on E
Apr. 2		eL.	20 03 38					Activity on N barely perceptible.
		eL.	20 03 05					
		M.	20 07 08	20	10			
		F.	20 25 ..					
		F.	20 11 ..					

TABLE 2.—Instrumental seismological reports, April, 1922—Continued.

VERMONT. U. S. Weather Bureau, Northfield.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Apr. 2	e.....	17 30					Very faint.
	F.....	17 40					
2	e.....	19 35					
	L.....	19 51	20				
	F.....	20 15					
5	e.....	10 35					
	F.....	10 55					
8	P.....	20 51 48					
	L.....	21 05	15				
	F.....	21 20 ca					
13	e.....	15 23					
	F.....	15 30					

CANADA. Dominion Observatory, Ottawa.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Apr. 2	e.....	17 05 30					Time breaks failed for duration of quake; time interpolated.
	eL.....	(17 15 30)					
	F.....	(17 19)					
2	O.....	(19 17 06)				(6,370)	
	P.....	19 26 58					
	IS.....	19 34 54					
	SR1.....	(19 38 48)					
	eL.....	19 43					
	L.....	19 50	18				
	L.....	20 10	15				
	F.....	21 ca.					
5	O.....	10 05 05				12,700	
	P.....	10 20 12					
	PR1.....	10 24 36					
	PR2.....	10 27 32					
	S.....	10 32 58					
	SR1.....	10 40 30					
	SR2.....	10 45 16					
	L.....	10 59					
	L.....	11 05	18				
	L.....	11 11 to					
	L.....	11 33	18				
	L.....	11 48	16				
	F.....	12 40 ca.					
6	e.....	(3 31 19)					Minute breaks failed; time interpolated.
	eL.....	(3 38)					
	L.....	(3 41)	34				
	L.....	(3 50 30)					
	F.....	(4 05 ca.)					
6	e.....	(8 18 36)					Traces only; poorly defined; minute breaks failed; time interpolated.
	L.....	(8 28)					
	L.....	(8 38)					
	F.....	(8 47)					
8	O.....	20 42 14				4,450	
	P.....	20 50 05					
	(PR2)	20 51 46					
	S.....	20 56 18					
	SR1.....	20 58 50					
	eL.....	21 01					
	M1.....	21 05	16				
	M2.....	21 12 30	10				
	F.....	22 05					
11	e.....	0 55 38					Sinusoidal L waves of distant quake.
	L.....	1 23	17				
	L.....	1 32	15				
	F.....	2 ca.					
11	eL.....	16 48					Faint traces only.
	F.....	17 16					
13	e.....	15 19 45					Irregular periods of moderate amplitude; not possible to distinguish phases.
	IS.....	15 22 00					
	L.....	15 23 10					
	L.....	15 24 00					
	eL.....	15 24 17					
	F.....	16 ca.					
17	e.....	7 25 30					Minute traces of disturbances; irregular periods.
	F.....	7 35					
20	e.....	5 55 44					Small sinusoidal L wave trace, mostly on E-W.
	eL.....	6 01 15					
	L.....	6 14					
	L.....	6 15	9				
	L.....	6 27	8				
	F.....	6 37					
25	e.....	21 43 50					
	eL.....	21 48 56					
	eL.....	21 56 00					
	L.....	22 04					
	L.....	22 24	19				
	L.....	22 31	17				
	L.....	22 44	19				
	L.....	22 46	17				
	L.....	23 01	15				
	F.....	24 00 ca.					

TABLE 2.—Instrumental seismological reports, April, 1922—Continued.

CANADA. Dominion Observatory, Ottawa—Continued.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Apr. 26	eL.....	2 00 00	28				Barely discernible L waves: sinusoidal.
	F.....	2 16					
26	e.....	4 17 48					Press report of a quake at Tokio, Apr. 26, at 10:15 a. m. does not coincide with these times exactly, but record seems to be of eastern quake. Micros.
	eL.....	4 21 04					
	eL.....	4 27 08					
	eL.....	4 42					
	L.....	4 55	17				
	L.....	4 47					
	e.....	5 13 52					
	F.....	5 50					
28	e.....	5 50 42					Micros.
	F.....	6 00					
28	eL.....	7 37					
	L.....	7 44	17				
	F.....	8 15					

CANADA. Dominion Meteorological Service, Toronto.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Apr. 2	M.....	17 20 18		*200			
	F.....	17 40 06?					
2	P.....	19 31 24					
	S.....	19 35 30					
	e.....	19 46 00					
	IL.....	19 50 36					
	IL.....	19 52 06					
	M.....	19 54 24		*2,000			
	eL.....	20 16 12					
	F.....	21 11 30					
5	P.....	10 27 42?					
	S.....	10 37 36					
	e.....	10 54 48					
	eL.....	11 07 30					
	eL.....	11 10 36					
	M.....	11 22 00		*2,200			
	F.....	12 26 36					
6	L.....	4 03 36					
	L.....	4 11 30		*100			
8	P.....	20 54 36				4,030	
	IS.....	21 00 24		*2,000			
	eL.....	21 02 48					
	eL.....	21 04 48					
	M.....	21 06 48		*9,000			
	F.....	22 06 48					
11	e.....	70 40 00					
	e.....	70 55 18					
	L.....	1 20 42					
	eL.....	1 22 42					
	M.....	1 31 00		*1,000			
	F.....	2 14 00					
16	eL.....	14 06 54					
	eL.....	14 09 12					
	M.....	14 15 00		*400			
	F.....	14 29 24					
20	L.....	6 14 06					
	L.....	6 32 48		*50			
25	L.....	721 49 42					
	eL.....	22 21 00					
	eL.....	22 31 24					
	eL.....	22 46 48					
	M.....	22 49 18		*1,200			
	F.....	70 19 54					
26	e.....	4 32 12					
	eL.....	4 50 30					
	M1.....	4 54 48		*600			
	eL.....	4 56 18					
	M2.....	5 01 06		*600			
	F.....	5 50 00					

CANADA. Dominion Meteorological Service, Victoria.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Apr. 2	L.....	2 03 31?					
	M.....	2 05 00		*200			
	F.....	2 09 25					
2	L.....	17 25 45					
	M.....	17 27 44		*200			
	F.....	17 37 40					
2	P.....	19 21 35					
	S.....	19 25 33					
	L.....	19 26 30					
	M.....	19 31 25		*2,250		1,070	
	F.....	21 11 15					

* Trace amplitude.

TABLE 2.—Instrumental seismological reports, April, 1922—Continued.

CANADA. Dominion Meteorological Service, Victoria—Continued.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Apr. 5	P.	10 22 34					Phases beautifully defined.
	S.	10 30 56					
	L.	10 42 44					
	M.	10 49 07					
	F.	12 43 13		*4,250		6,860	
6	P.	3 52 53					
	M.	3 56 29		*250			
	F.	4 01 15					
6	M.	8 44 29		*100			
8	P.	20 57 50					
	S.	21 01 47					
	L.	21 05 13					
	M.	21 10 08		*8,000		2,400	
	F.	21 55 52					
10	L.	4 34 02					
	M.	4 36 59		*200			
	F.	4 43 52					
11	P.	0 42 07					
	S.	0 47 05					
	L.	0 57 00					
	eL.	0 59 30					
	M.	1 03 57		*1,000		3,200	
	F.	1 50 33					
11	M.	2 53 04		*100			
16	L?	14 15 59					
	eL.	14 23 42					
	M.	14 25 24		*200			
	F.	14 35 09					
20	L.	6 09 18					
	M.	6 13 14		*250			
	F.	6 23 04					
25	L.	21 41 14					
	eL.	22 00 36					
	M.	22 04 03		*700			
	eL.	22 24 18					
	F.	23 56 07					
26	S?	4 15 23					
	L.	4 21 50					
	M.	4 35 13		*400			
	F.	5 19 51					
	VERTICAL.						
2	P.	19 22 35				730?	
	S.	19 23 55					
	L.	19 27 25	10				
	M.	19 30 25		3			
	F.	?					
5	S.	10 31 10					
	L.	10 44 29	25				
	M.	10 50 50		3			
8	P.	20 57 00					
	S.	21 01 30					
	L.	21 09 00	15				
	M.	21 13 50	15	9		2,830	

* Trace amplitude.

At Fordham University, New York, N. Y., earthquakes were recorded on the 5th, 24th, and 25th, but the clock was out of order and there was no time record.

No quakes were recorded during April, 1922, at the following stations:

CALIFORNIA. Theosophical University, Point Loma.

CANAL ZONE. Panama Canal, Balboa Heights.

No reports for April, 1922, have been received from the following stations:

ALABAMA. Spring Hill College, Mobile.

DISTRICT OF COLUMBIA. Georgetown University, Washington.

MASSACHUSETTS. Harvard University, Cambridge.

TABLE 3.—Late reports (instrumental).

DISTRICT OF COLUMBIA. Georgetown University, Washington.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Feb. 14	L.	14 01 ..	26				Heavy micros; N-S does not show.
	F.	14 10 ..					
16	eP.	3 20 43					Heavy micros.
	eS.	3 25 32					
	eS.	3 25 38					
	eL.	3 27 48	8				
	M.	3 32 28		*2,200			
	M.	3 32 13			*1,300		
19	eL?	22 06 24					Heavy micros; no distinct M.
	L.	22 09 16					
	L.	22 07 33	19				
	F.	22 26 ..					
20	eL.	8 40 36					Heavy micros; E-W does not show.
	F.	8 50 ..					
28	eL.	21 31 48	18				Difficult; heavy micros; E-W does not show.
	F.	21 40 ..					
Mar. 4	eP.	13 19 ..					Very heavy micros.
	P.	13 19 12					
	i.	13 20 05					
	i.	13 20 08					
	iS.	13 23 40					
	S.	13 28 43					
	eL.	13 40 24					
	L.	13 45 ..	12				
	L.	13 54 33	16				
	F.	14 10 ..					
10	eP.	11 34 42					Very heavy micros. P possibly sooner.
	S.	11 39 59					
	eL.	11 42 24	10				
	eL.	11 42 06	10				
	M.	11 43 39		*2,300			
	M.	11 42 12			*2,000		
	F.	12 10 ..					
10	i.	17 15 13					Very heavy micros. Lost in micros.
	F.						
22	e.	22 33 46					Very heavy micros.
	e.	22 34 ..					
	F.	22 37 ..					
28	eP.	4 08 ..					Heavy micros; no distinct M.
	iP.	4 07 56					
	iS.	4 16 05					
	iS.	4 16 04					
	eL?	4 26 18	11				
	eL.	4 26 18					
	L.	4 36 04					
	F.	4 47 ..					

ARIZONA. U. S. C. & G. S. Magnetic Observatory, Tucson.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Mar. 10	P.	11 19 54	2				N not in operation; L doubtful; recorded on D, H, and Z variometers.
	L.	11 21 23	12				
	M.	11 22 40	14	10,800			
	C.	11 23 28					
	F.	11 37 ..					
28	iP.	4 08 40				7,340	Max. on E occurs at 4:18:27, ampl. 0.1 mm.; on N at 4:08:44, ampl. 0.1 mm.; no definite max. during L phase.
	iS.	4 17 26					
	L.	4 31 36					
	F.	4 36 ..					
	F.	4 26 ..					

* Trace amplitude.

TABLE 3.—Late reports (instrumental)—Continued.

MARYLAND. U. S. C. & G. S. Magnetic Observatory, Cheltenham.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Mar. 10	eL _N	11 35 29					
	e _N	11 40 ..					
	e _N	11 40 09	10				
	M _N	11 43 22	9	* 200			
	M _N	11 43 02	10		* 1,500		
	C _N	11 45 10					
	F _N	11 53 ..					
	F _N	11 57 ..					
28	IP _N	4 07 47				6,480	Max. on E occurs during S at 4:15: 52 ampl. 0.1 mm.
	iS _N	4 15 49					
	SR2 _N	4 21 33	12				
	L _N	4 25 41					
	M _N	4 36 43	20		* 100		
	C _N	4 37 15					
	F _N	4 28 ..					
	F _N	4 45 ..					

HAWAII. U. S. C. & G. S. Magnetic Observatory, Honolulu.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Mar. 4	P _N	13 15 54	6				L phase poorly defined: actual M occurs on E at 13:22:35, ampl. 5.3 mm.; on N at 13:27:18, ampl. 4.4 mm.
	PR1 _N	13 17 29	6				
	S _N	13 22 21	11				
	S _N	13 22 33					
	SR1 _N	13 25 30					
	SR1 _N	13 25 20					
	SR2 _N	13 26 50					
	SR2 _N	13 26 41	12				
	L _N	13 28 55	13				
	L _N	13 29 03	16				
	F _N	13 56 ..					
	F _N	14 07 ..					
10	L _N	11 38 22					No definite M on E.
	L _N	11 36 27					
	M _N	11 38 18	10		* 2,500		
	F _N	11 55 ..					
	F _N	11 53 ..					
10	i _N	17 06 27	7	* 3,400	* 4,000		Most of record lost through changing paper. May not be seismic.
12	e _N	17 39 ..					Nothing definite on E.
	e _N	17 38 09					
	L _N	17 43 14	18				
	M _N	17 45 ..	18		* 1,300		
	F _N	17 55 ..					
	F _N	17 52 ..					

* Trace amplitude.

TABLE 3.—Late reports (instrumental)—Continued.

HAWAII. U. S. C. & G. S. Magnetic Observatory, Honolulu—Contd.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Mar. 26	e _N	13 58 16					Nothing definite. Sensitivity after March 15: N, 28.4 mm.; E, 26.8 mm.
	F _N	14 16 ..					
	F _N	14 27 ..					
28	S _N	4 22 58				10,700	Other phases indefinite: actual M occurs on E 5:25:30, ampl. 2.0 mm.; on N 5:30: 25, ampl. 2.0 mm.
	S _N	4 23 34					
	SR1 _N	4 29 37					
	SR1 _N	4 29 50					
	F _N	4 54 ..					
	F _N	5 09 ..					

PORTO RICO. U. S. C. & G. S. Magnetic Observatory, Vieques.

1922.		H. m. s.	Sec.	μ	μ	Km.	
Mar. 23	P _N	4 52 48					Local tremor; L doubtful.
	L _N	4 53 14					
	L _N	4 53 04	2				
	M _N	4 53 16	2	* 200			
	M _N	4 53 10	2		* 200		
	C _N	4 53 22					
	F _N	4 56 ..					
	F _N	4 58 ..					
23	e _N	5 52 16	2				Very slight tremor
	e _N	5 55 17					
	F _N	5 55 40					
	F _N	5 58 ..					
26	P _N	23 37 12					Local; recorded on H variometer at 23:37.
	L _N	23 38 10					
	L _N	23 37 58	3				
	M _N	23 39 24	7	* 600			
	M _N	23 38 33	5		* 500		
	F _N	23 47 ..					
28	P _N	4 05 11				3,900	Actual M on N occurs during S at 4:11:02; ampl. 0.4 mm.; L weak.
	iS _N	4 10 52					
	L _N	4 13 58					
	L _N	4 14 26					
	M _N	4 14 28		* 1,300			
	F _N	4 21 ..					
	F _N	4 17 ..					

* Trace amplitude.

Chart I. Tracks of Centers of Anticyclones, April, 1922. (Inset) Departure of Monthly Mean Pressure from Normal. (Plotted by Wilfred P. Day.)

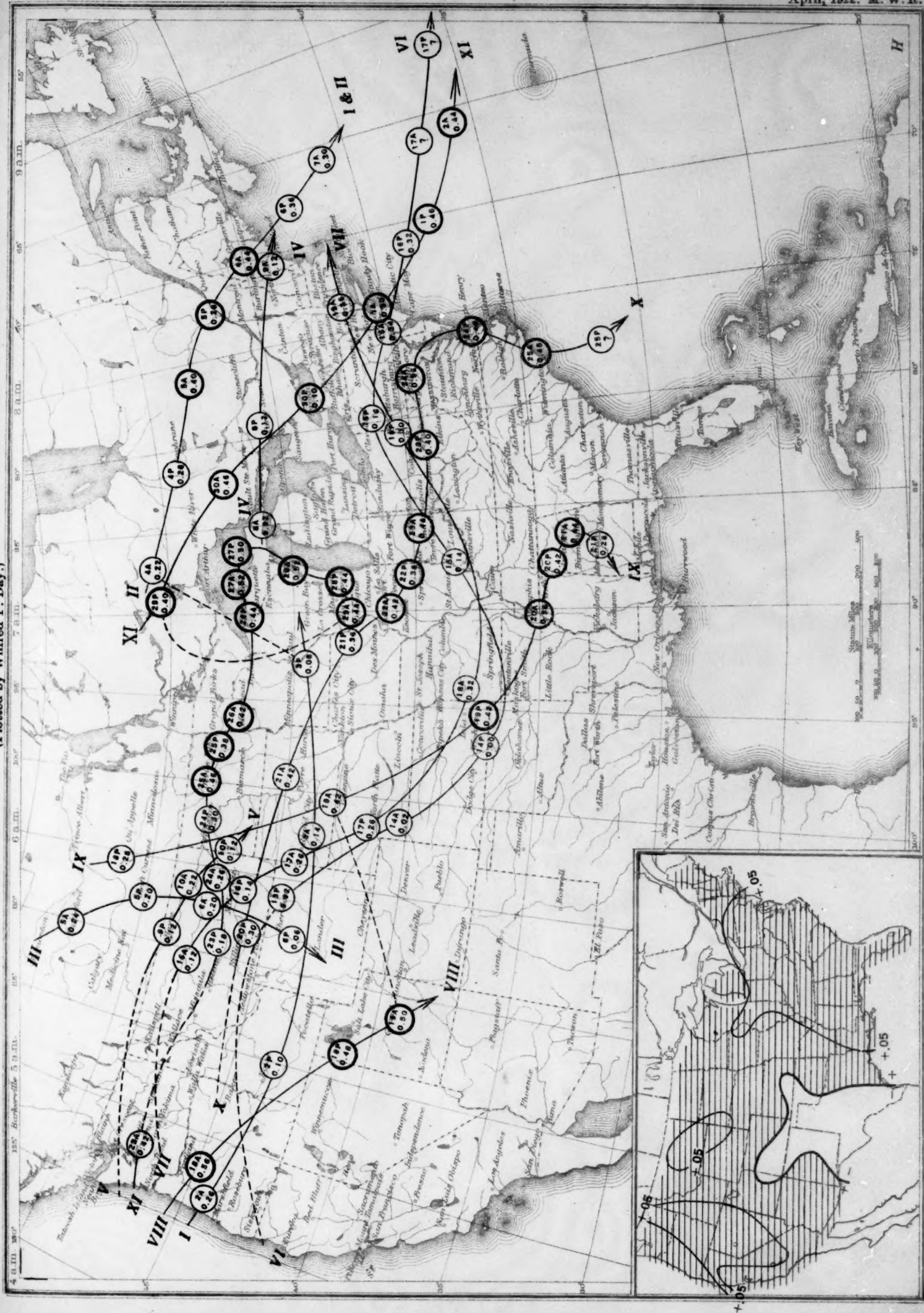


Chart II. Tracks of Centers of Cyclones, April, 1922. (Inset) Change in Mean Pressure from Preceding Month.
(Plotted by Wilfred P. Day.)

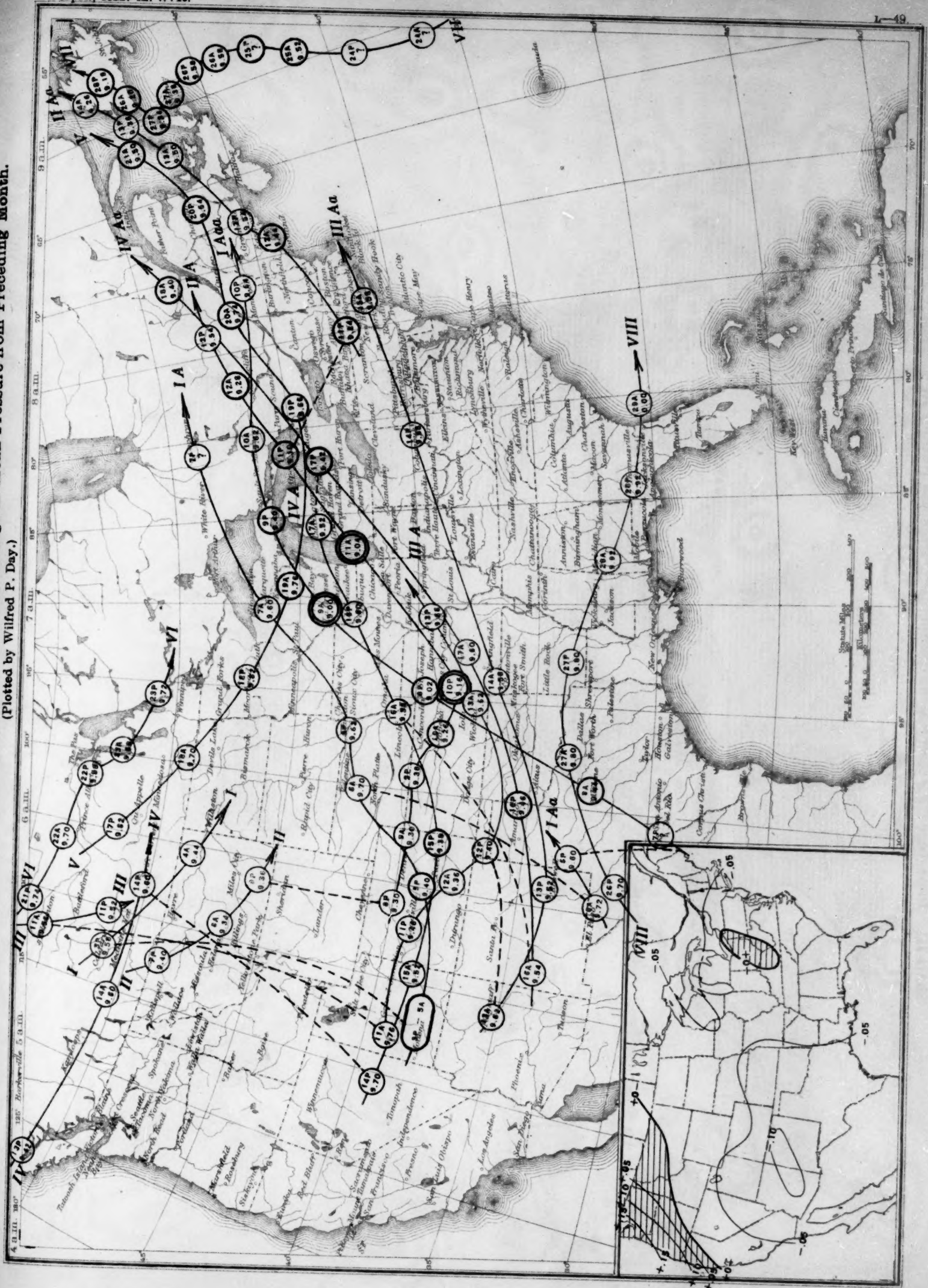
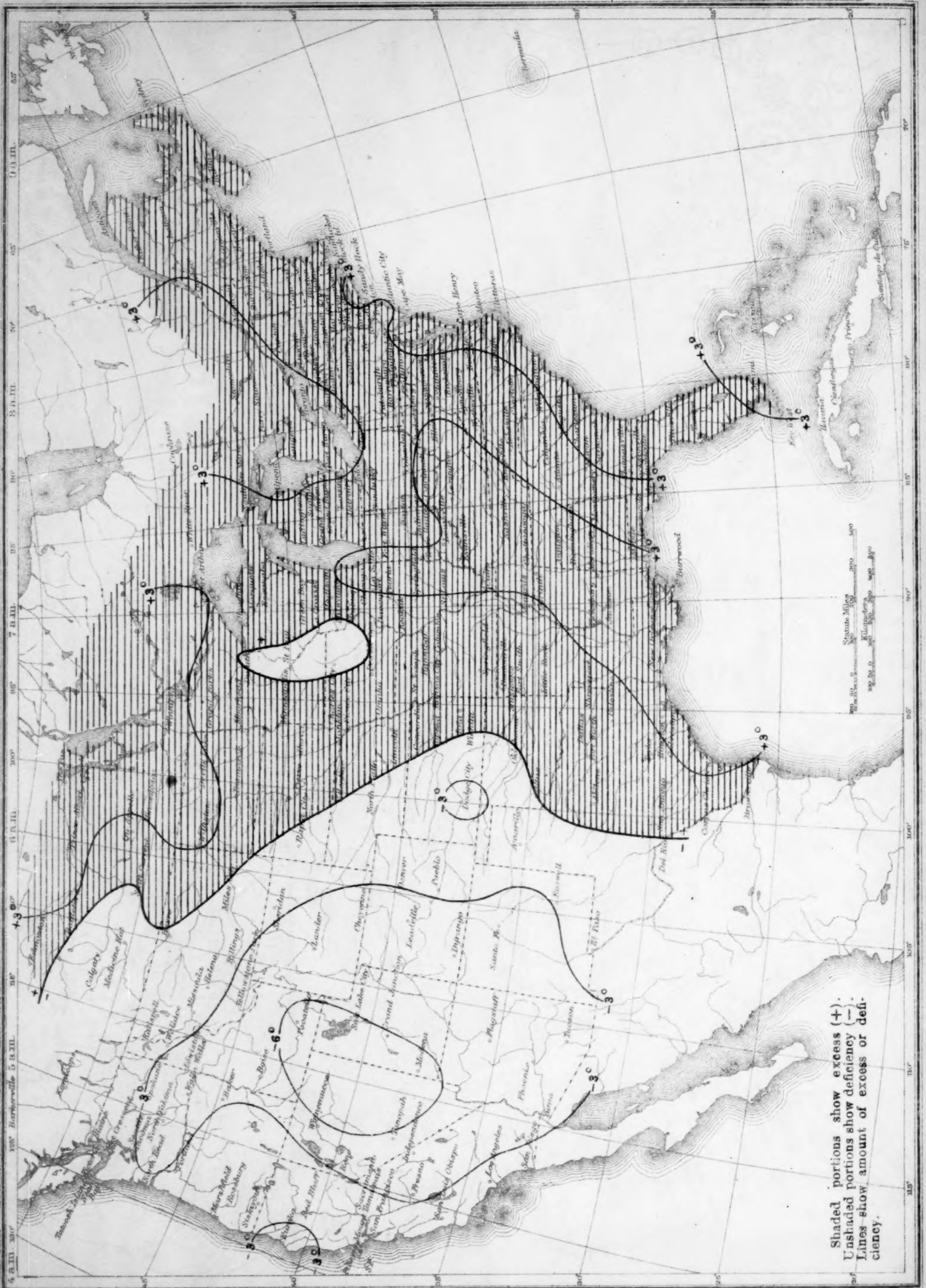


Chart III. Departure (°F.) of the Mean Temperature from the Normal, April, 1922.



Shaded portions show excess (+).
Unshaded portions show deficiency (-).
Lines show amount of excess or deficiency.

Chart IV. Total Precipitation, Inches, April, 1922. (Inset) Departure of Precipitation from Normal.

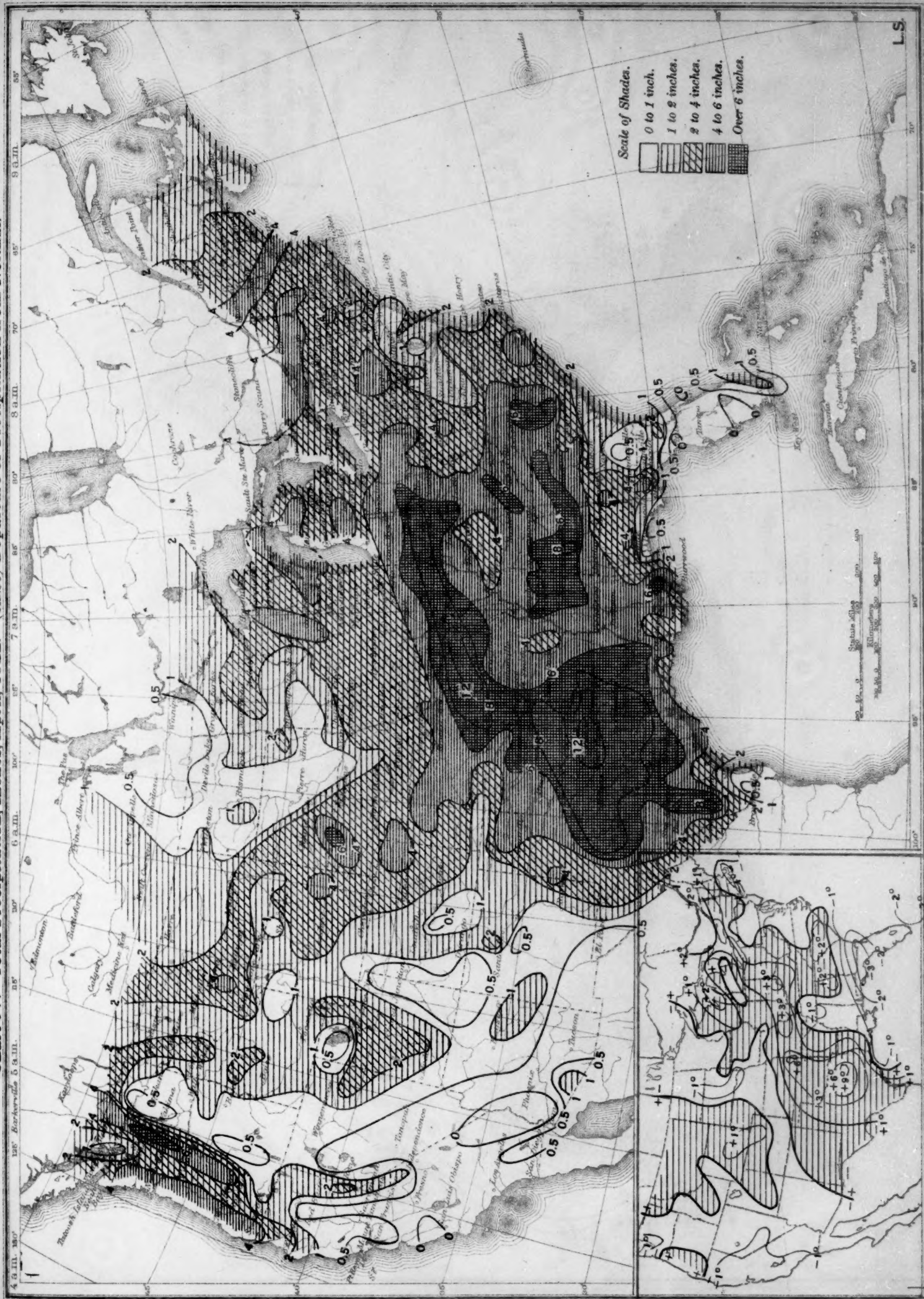
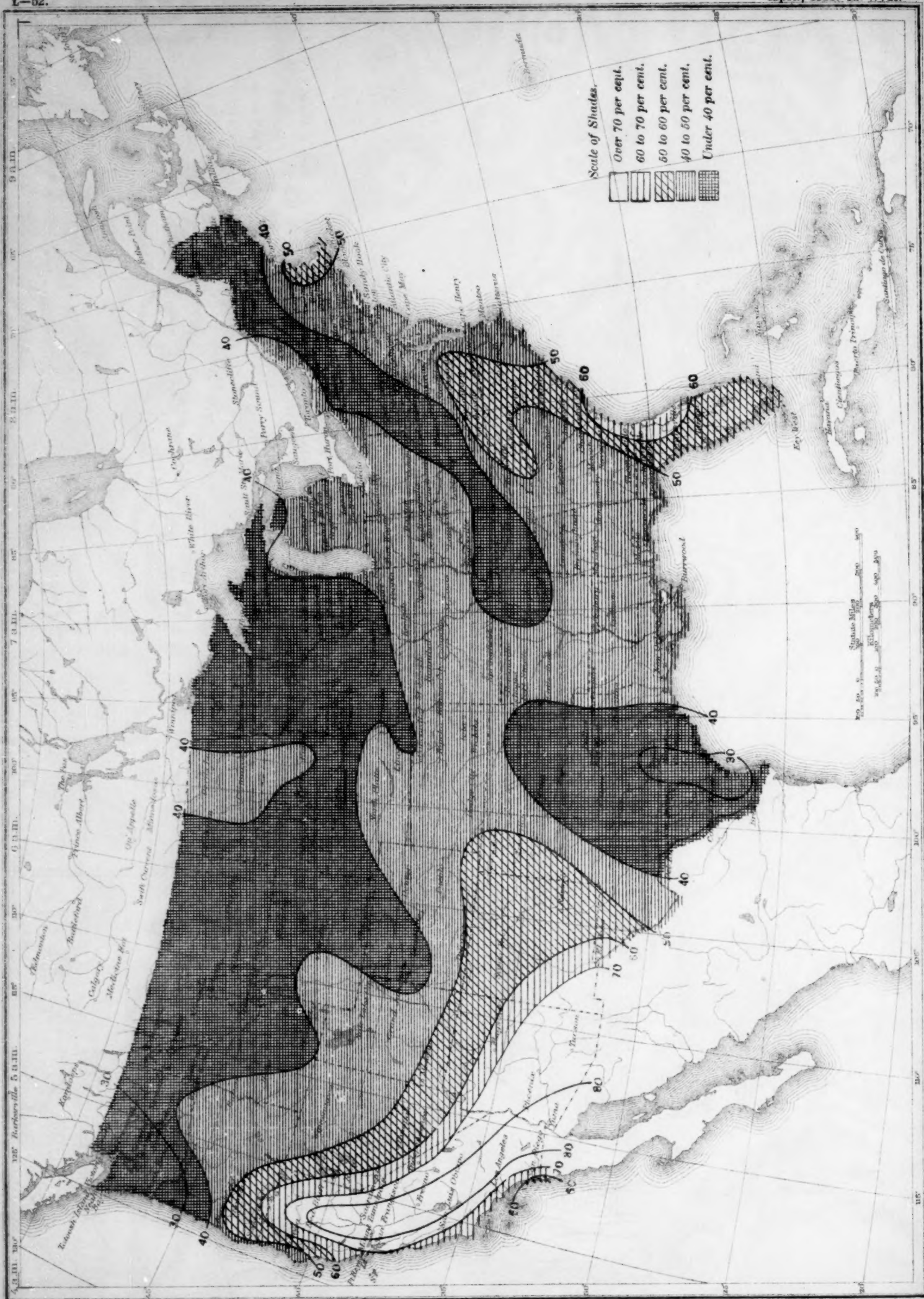


Chart V. Percentage of Clear Sky between Sunrise and Sunset, April, 1922.



This is a detailed map of the central United States, showing isobars for April 1922. The map covers the area from 125°W to 75°W and 25°N to 45°N. Isobars are labeled with values such as 29.95, 30.00, 30.05, and 30.10. Major cities like St. Louis, Chicago, and Kansas City are marked. The map includes state boundaries and a scale bar in both kilometers and statute miles.

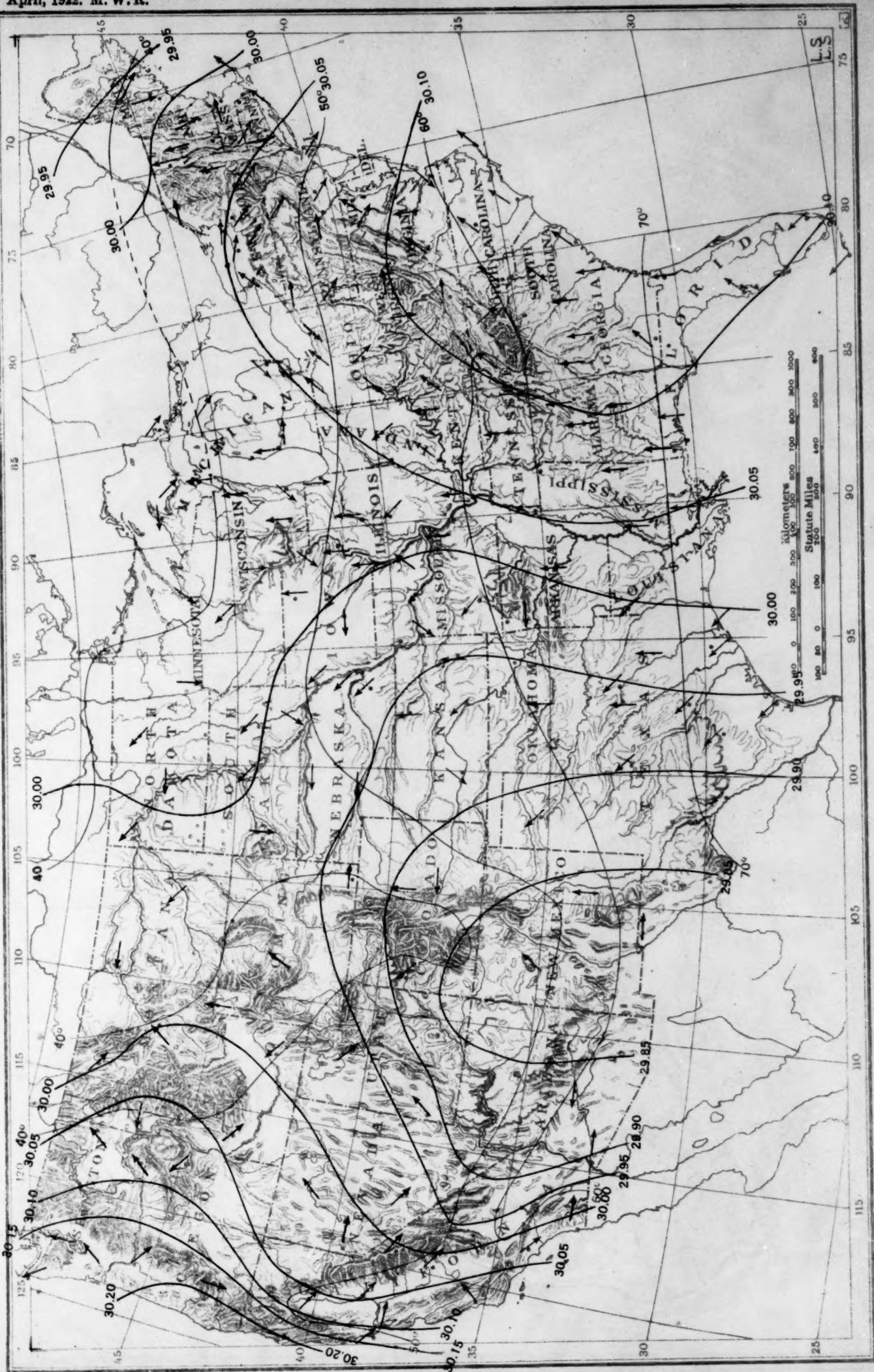
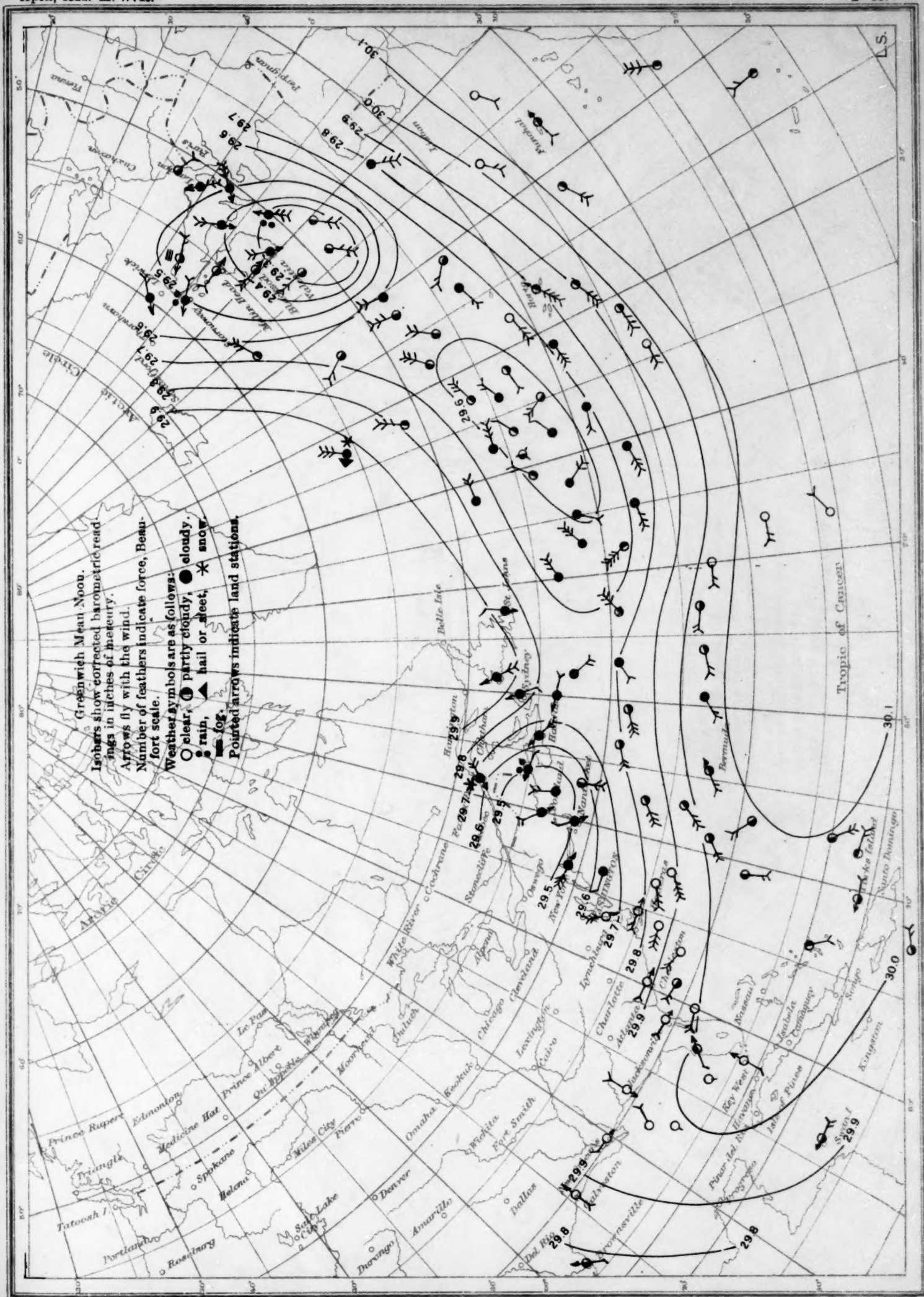


Chart VII. Total Snowfall, Inches, April, 1922.

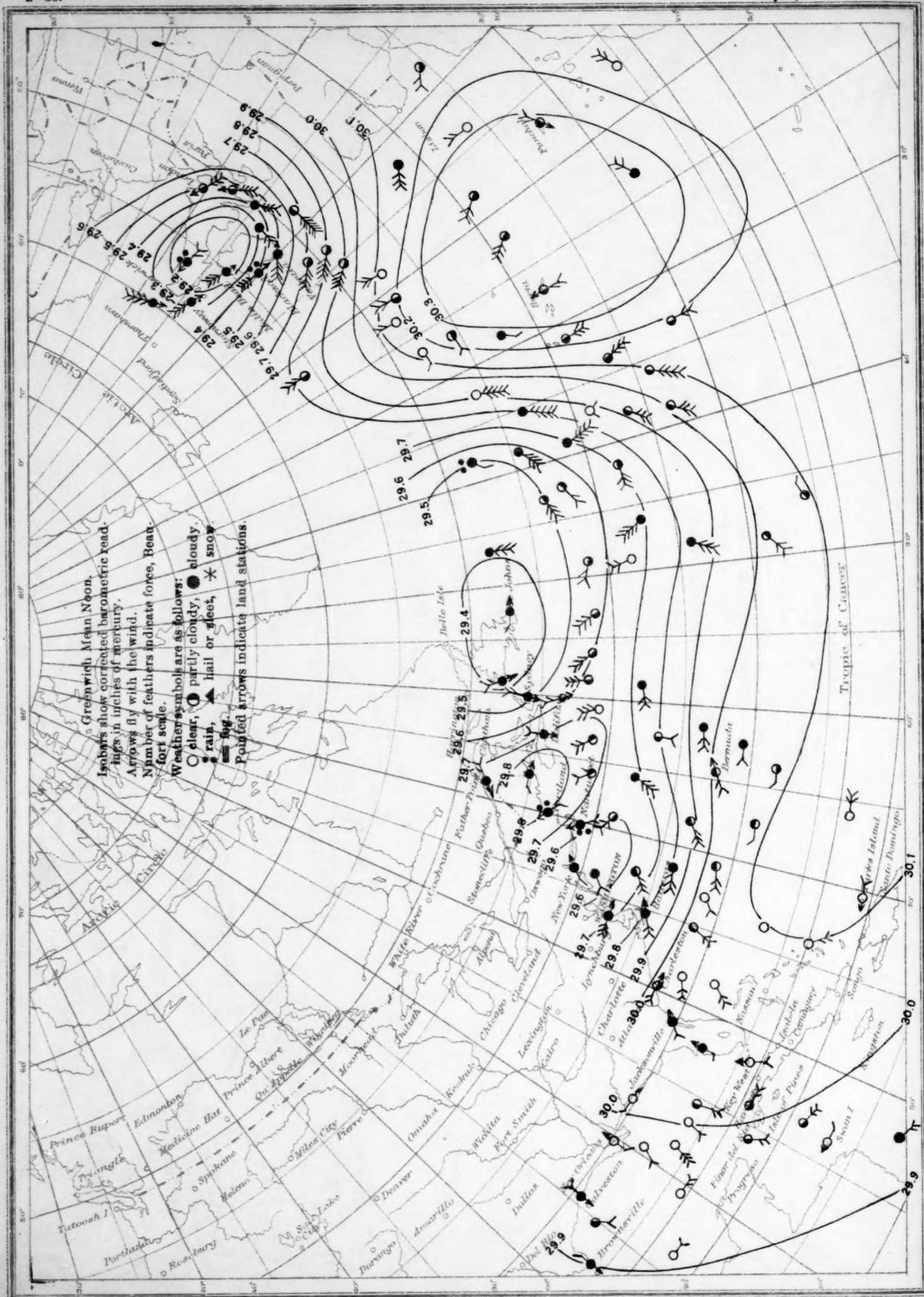


Chart VIII. Weather Map of North Atlantic Ocean, April 12, 1922.
(Plotted by F. A. Young)

(Plotted by F. A. Young.)



(Plotted by F. A. Young.)



(Plotted by F. A. Young.)

Chart X. Weather Map of North Atlantic Ocean, April 14, 1922.

(Plotted by F. A. Young.)

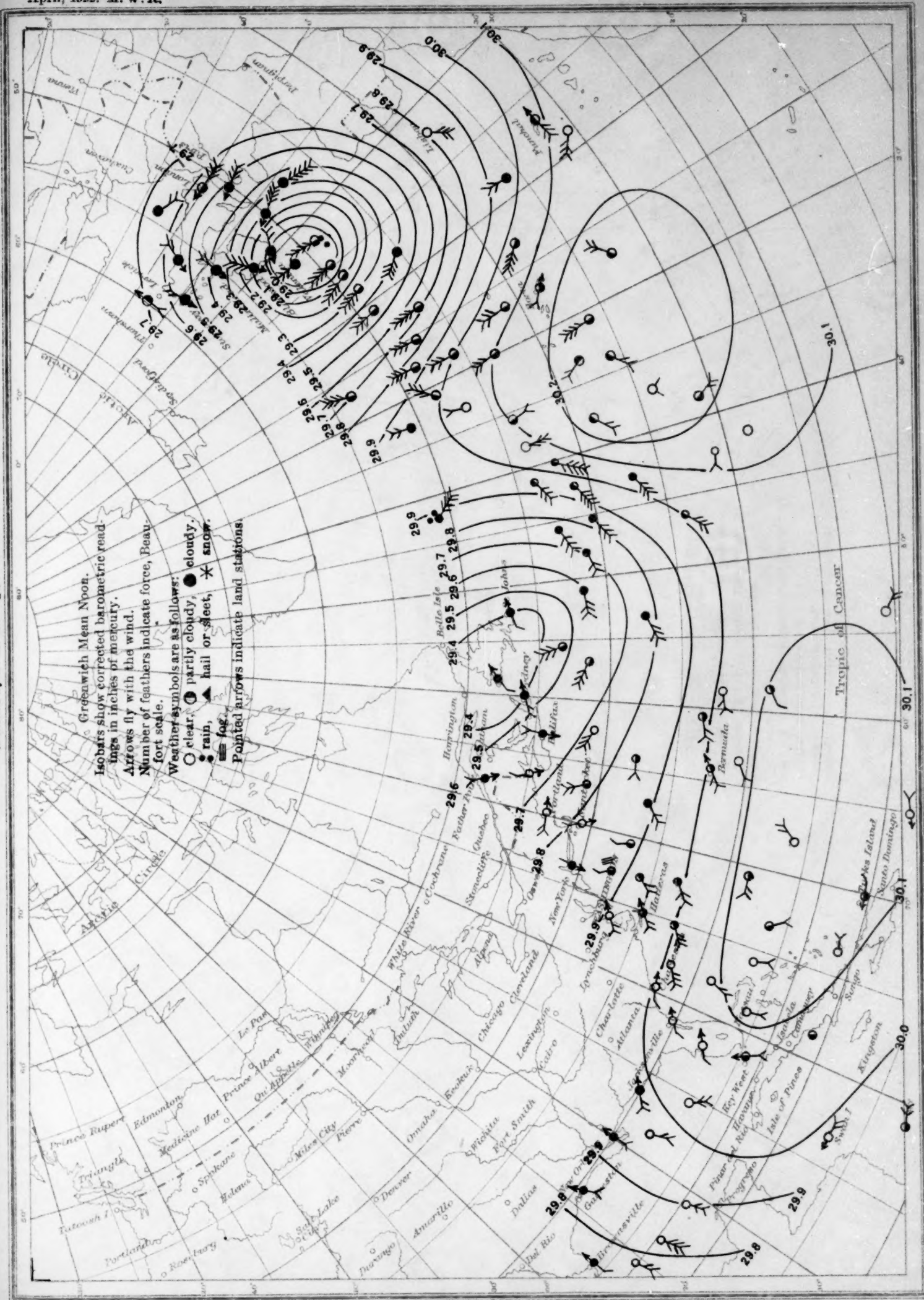
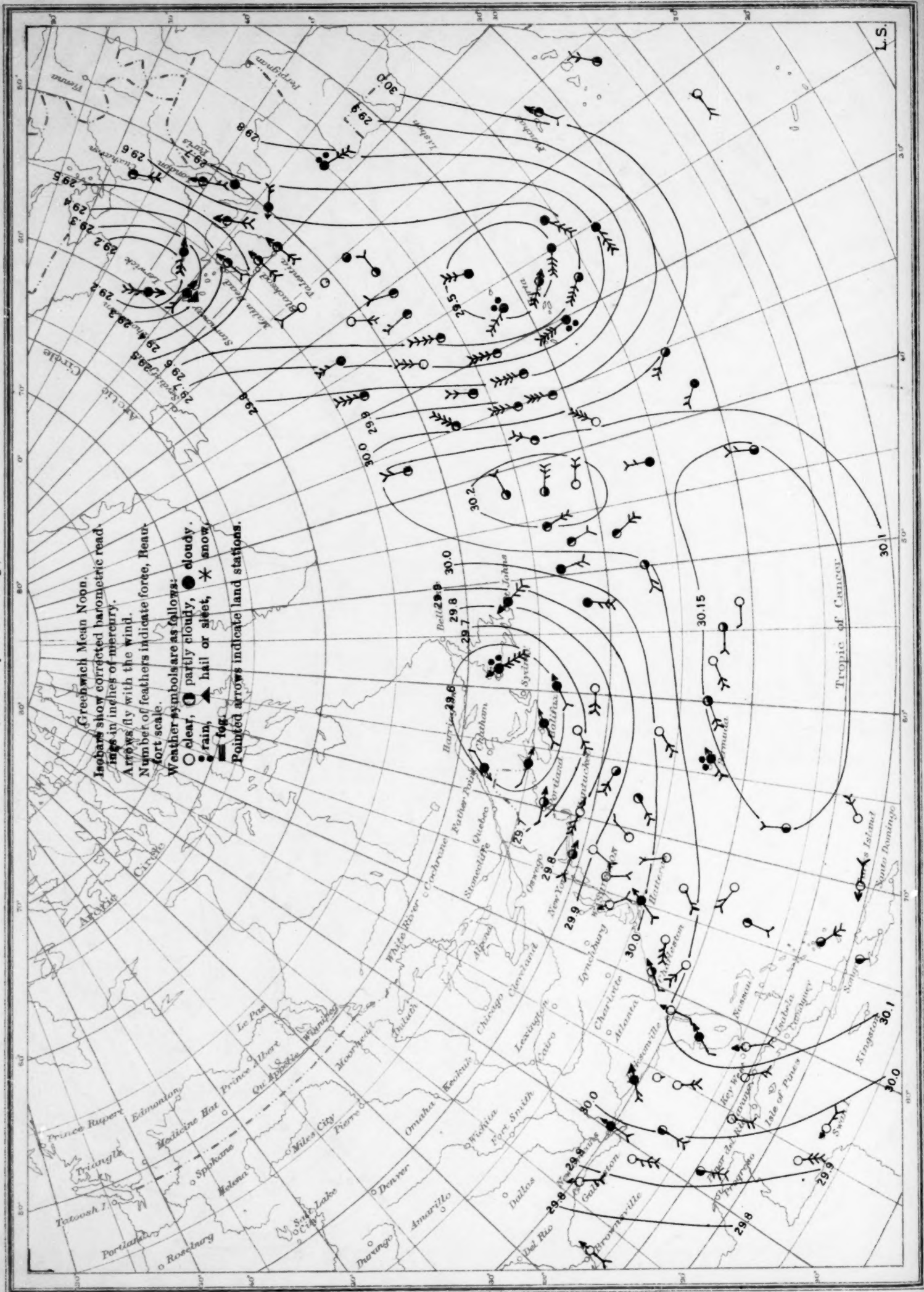


Chart XI. Weather Map of North Atlantic Ocean, April 15, 1922.
(Plotted by F. A. Young.)



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APRIL, 1922.

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CORRIGENDA.

JANUARY, 1922:

Page 1, in headline, volume number "49" should be "50."

FEBRUARY, 1922:

Page 55, in headline, volume number "49" should be "50."

Page 69, second column, second line from top, the sentence beginning "The northwest and east" should read "northeast and east."

MARCH, 1922:

Page 117, in headline, volume number "49" should be "50."